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THE TAXONOMY OF AMERICAN COMMERCIAL SPONGES¹

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ABSTRACT

The taxonomy of the American commercial sponges is revised and four new species and one new subspecies are described, including one new species of commercial sponge, hitherto unrecognized, from the Mediterranean. The eleven species treated herein are: *Spongia obliqua*, *Spongia barbara*, *Spongia barbara dura*, *Spongia anclotea*, new species, *Spongia sterea*, new species, *Spongia graminea*, *Spongia graminea tampa*, new subspecies, *Spongia cheiris*, new species, *Hippiospongia gossypina*, *Hippiospongia lachne*, and *Hippiospongia kerion*, new species from the Mediterranean. All are illustrated.

INTRODUCTION

The commercial "sponge" is the macerated and dried skeleton of one of the sponge animals that has no proper spicules. It must be from a species whose skeleton consists of spongin fibers, and furthermore these fibers must continue to be elastic or "spongy" even after having been dried; this is not true of all sponges. Some 1400 genera of sponges have been described, but only two of these yield skeletons that have market value. Sponges are abundant in cool water, but grow very slowly in such environments. Only in warm water, such as that of the Mediterranean and West Indies, do they grow so rapidly as to have commercial possibilities.

Sponges of the eastern Mediterranean Sea, near Greece and Turkey, have the best quality for human use. Greek fishermen have collected and marketed sponges for at least three thousand years.

¹Contribution No. 193 from The Marine Laboratory, University of Miami.

Sponges of the eastern Gulf of Mexico, along the west coast of Florida, have quality nearly as good as the Greek sponges. For somewhat more than a century a sponge industry has been maintained in Florida, and to a lesser extent in the whole West Indian region. This has been surpassed in volume and quality only by the above-mentioned Mediterranean sponge industry. It was first maintained by American fishermen, with a marketing center at Key West, but about 70 or 80 years ago the principal market shifted to Tarpon Springs, and more and more of the harvesting was done by Greeks.

In late 1939 and early 1940, an epidemic of disease swept through the commercial sponges of the Americas. A small fraction survived, but the Greeks refused to accept conservation measures whereby these survivors could quickly replenish the denuded areas. They sought all remaining sponges so assiduously that from 1944 to 1954 American sponges practically vanished from the market. Since 1955, however, they have been coming back.

American commercial sponges fall into nine categories, with vernacular names that are well established in some localities, but not in others, with two or more national languages also involved. Because of this confusion, the proper establishment of the scientific names is more than usually important and is the subject of the present paper.

The senior author has studied the sponges of the world for a third of a century, with field experience in many parts of the globe, including some in the Mediterranean and much in the West Indies. Work was carried out underwater with diving apparatus, as well as in extensive collections.

The junior author has spent even more time underwater working with air hose and face mask which permit great freedom of action. His studies were made during 1955-57 and included more than 125 days of submarine exploration, chiefly at depths of 10 to 20 meters. Especial attention was paid to the area along the west coast of Florida, which is the best for commercial sponges. The studies were uniformly distributed through the twelve months of the year, and the daily average was ten "dives" of half an hour each, a total of over 625 hours. Emphasis was constantly placed on ecology, the relation between environment and the sponges.

The operation of environment warrants attention. Each sponge has its characteristic shape, and species theoretically should be identifiable on the basis of shape alone. Yet for each species a variety of shapes actually occur. Museum workers are thus faced with a quandary

and two extremes of policy have resulted. One was a multiplication of superfluous names based upon environmental modifications of a single species. The other was a conclusion that sponges were so easily molded that shape was meaningless; this has led to erroneous "lumping" of several species under a single name.

The environment can certainly subtract from the ideal assortment of characteristics, even to producing deformed and extremely stunted results, but it cannot add. The statement that sponge animals are "plastic" is true but misleading. The environment is not a constructive sculptor that can make a symmetrical vase-shaped sponge out of one that is naturally, intrinsically, or genetically merely an encrusting mass, but it can reduce a naturally vase-shaped sponge to an amorphous "blob." Radical temperature changes are especially potent in causing just such deformation . . . The ideal environment is one that does not damage, but instead permits the fullest expression of the intrinsic nature.

Modern nomenclature dates by common agreement from the publication in 1758-1759 of the tenth edition of the epoch-making book "Systema Naturae" by Carl Linnaeus. In 1759, page 1348, he put not only all the commercial sponges, but all the others as well, into a single genus *Spongia*; he had all the commercial sponges as *S. officinalis*. By 1859 all the others had been removed, and in that year H. G. Bronn proposed removing even *Spongia* into what he called "*Euspongia*." This was, of course, illegal, and the name *Spongia* must stand. Unfortunately, many publications employ the unwarranted name *Euspongia*.

The fact that commercial sponges fall into two distinct categories, each a genus, is the definite judgment here expressed. It was first recognized by F. E. Schulze (1879, p. 614) when he took some from *Spongia* into his new genus *Hippospongia*.

The eminent spongologist M. Burton of the British Museum (Natural History) believes that all the commercial sponges should remain in *Spongia*. Therefore, in 1934, page 575, he established a neotype specimen of *Hippospongia* that does not fit the second category, but instead is a typical *Spongia*. Schulze had not designated a type specimen, therefore Burton's action was legal and in order. It reduced *Hippospongia* to synonymy with *Spongia*.

The second category was again given generic standing by deLaubenfels (1936, p. 11) who set up the genus *Hippiospongia*, purposely choosing a name as much as possible like Schulze's obviated name.

Hippiospongia is protected by a carefully designated type specimen, which is number 801 in the United States National Museum.

American sponges in some cases resemble certain European sponges. It has been suggested that they are merely subspecies of the European ones, rather than full species. For example, the senior author in 1948 cited the American "yellow" sponge, *Spongia barbara*, as merely a subspecies of the Mediterranean "zìmocca" sponge. This decision was made with great hesitation, and is here revoked. The sort of observations involved in this later decision may be exemplified by a study of certain non-commercial sponges.

Sponge animals of the genus *Cliona* bore tunnels into solid limestone, especially oyster shells. *Cliona celata* and *Cliona caribboea* were differentiated for about seventy years only because the latter excavates slightly larger tunnels. Naturally there was criticism that this was a minor point, and that the two must belong to the same species. Old *Clionas* outgrow their hiding places and become exposed massive sponges; this form of *celata* has been well known for nearly a century. Recently the senior author has found corresponding old, massive specimens of *caribboea*; it turns out that they differ radically in several ways from the corresponding *celata* forms, proving that each is a valid separate species.

The American commercial sponges are completely allopatric with respect to the European ones. Whether or not they could interbreed is highly speculative. Subspecific designation requires a trinomial, and this is not so convenient as a binomial. The more one studies the sponges, the more points of difference are found. Thus a conclusion is reached which involves great skepticism concerning the hypothesis that any West Indian sponge is specifically identical (conspecific) with any Mediterranean sponge. In this connection, attention may be called to Ekman's masterly volume "Zoogeography of the Sea." In this summary of a vast literature Ekman points out that very few species in any phylum occur both in the Mediterranean and also in the West Indies. It is merely that corresponding types occupy corresponding ecological niches.

This paper constitutes a partial report to the U. S. Fish and Wildlife Service which supported the work of the junior author on a grant to survey the commercial sponge grounds off Florida. The work commenced in June, 1955 and terminated in August, 1957. The complete report by the junior author dealing with the ecology, growth and reproduction of sponges, the physical characteristics of the grounds and

economics of the fishery will be published in the near future as a bulletin of the U. S. Fish and Wildlife Service.

SYSTEMATICS

Genus *Spongia* Linnaeus, 1759

Spongia Linnaeus, 1759, p. 1348.

Sponges of this genus have protoplasmic structures such as are considered typical for RHAGON architecture, with extremely abundant diplodal flagellate chambers. There is a dermis, partly protoplasmic, partly spongin, 30 to 70 microns thick; it covers the surface of the sponge, but is pierced by oscules (exhalant) and by numerous pores (inhalant). The skeleton consists of a network of spongin fibers, which are 5 to 35 microns in diameter, most frequently 15 to 20 microns in diameter. The meshes are almost rectangular in outline, with dimensions varying from 100 microns to a millimeter. At distances nearly a millimeter apart, another type of fiber ascends from the interior of the sponge to the surface. These ascending fibers are 30 to 100 microns in diameter, and contain a nearly continuous core of foreign debris, which may consist of fine sand grains, or fragments of the spicules of spiculiferous sponges, or both.

Spongia obliqua Duchassaing and Michelotti, 1864

REEF SPONGE

Fig. 5

Spongia obliqua Duchassaing and Michelotti, 1864, p. 38.

This species was extremely widespread before the epidemic of 1940, chiefly in water less than five meters deep. It vanished almost completely in the epidemic, but in 1957, Mr. Frank Swift found one in Biscayne Bay, and a few have been recorded from the southern Bahamas.

This is the American sponge that most nearly corresponds to the European *Spongia officinalis*, but whereas that species has maximum commercial value (highest quality), *obliqua* has nearly no commercial value at all.

Reef sponges are often about the size of a human fist, seldom much larger. The shape is massive, with flat or plane areas at obtuse angles to one another, so that it is evident why its authors chose "obliqua" as a name.

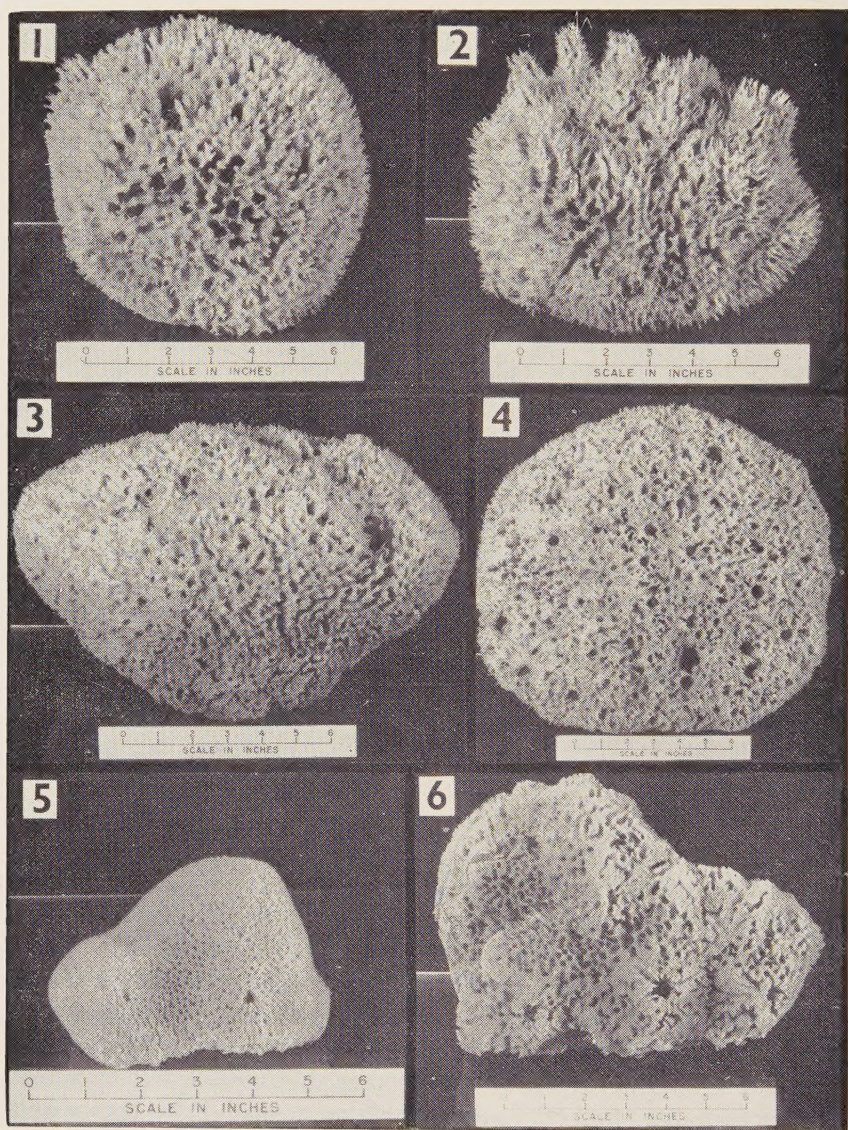


FIGURE 1. Rock Island wool sponge (*Hippiospongia lachne*). FIGURE 2. Wool sponge from strong tide area with chimneys around oscules. FIGURE 3. Mediterranean honeycomb or wool sponge—side view (*Hippiospongia kerion*). FIGURE 4. Top view of honeycomb sponge. FIGURE 5. Reef sponge (*Spongia obliqua*). FIGURE 6. Wire sponge (*Spongia sterea*).

The external color in life is black, with an ochraceous to rust-red interior.

The surface is finely conulose, conules less than one millimeter high, and only one or two millimeters apart. The entire lateral surface of the sponge is crowded with pores that are less than a millimeter in diameter, about three millimeters apart. The oscules are only three to four millimeters in diameter, and are located on the upper surface.

Spongia barbara Duchassaing and Michelotti, 1864

YELLOW SPONGE

Figs. 13, 14, and 20

Spongia barbara Duchassaing and Michelotti, 1864, p. 31.

This was treated as *Spongia zimocca*, subspecies *barbara* in deLaubenfels 1948, page 13, but the synonymy with *zimocca* was not then certain, and now appears completely uncertain.

Spongia barbara is abundant at least throughout the Florida Keys and the eastern Gulf of Mexico. Specimens as large as a human head are often found. The shape obviously tends toward being spherical or spheroidal.

The color in life is dark sepia, almost black, when the sponge grows at depths of less than two meters. At depths of ten meters this species is more abundant, and at that depth is always a yellowish-drab, grey-yellow or yellowish taupe in color. It is true of sponges in general that the greater the illumination where they grow, the darker is their pigmentation, but no other commercial sponge exhibits this color difference so strikingly as does *barbara* and few noncommercial sponges match it. The interior of the sponge, like nearly all commercial sponges, varies from yellow-ochre to rust red. The fibers of the macerated, dried yellow sponge are slightly but definitely more yellowish than the fibers of other commercial sponges.

The surface is finely conulose, much as in *obliqua*. The pores are somewhat larger but farther apart, say four or five millimeters on centers. Each specimen generally has ten to twenty oscules on its uppermost surface, each seven to ten millimeters in diameter, most often eight or nine millimeters. These oscules are never surmounted by thin walled sleeves or "chimneys."

The surface of a yellow sponge from shallow water, with the dermis removed and the skeleton macerated as in the usual preparation for marketing, may show an interesting configuration. The surface growth

to a depth of two centimeters may consist of cylindrical knobs or tufts, with flattened or slightly rounded apices, not tapering conically, nor enlarged at their tips. These knobs are three to four millimeters in diameter, and about twice that distance apart (on centers). This configuration bears a superficial resemblance to that of *Hippiospongia*, especially *H. gossypina*. On the yellow sponge, however, each such knob contains several ascending fibers, conspicuously thicker and straighter than the ordinary fibers; no such ascending fibers occur in *Hippiospongia*. Furthermore, in the latter genus, the corresponding knobs taper conically from base to tip in the "wool" sponge, and tend to be enlarged at the tips in the "velvet."

Spongia barbara dura Hyatt, 1877

HARDHEAD SPONGE

Fig. 17

Spongia agaricina dura Hyatt, 1877, p. 522.

This was treated as *Spongia officinalis* subspecies *dura* by deLaubenfels (1948, p.8). The extensive field experience of the junior author of this paper leads to the present conclusion that the hardhead is a modified "yellow" rather than a modified "reef" sponge.

"Hardhead" sponges are common in the Bahamas, where they completely replace the "yellow" sponges. They seem to be absent elsewhere, where typical *barbara* occurs. They are much like "yellow" sponges, but not so yellow, and their fibers are much harder and stiffer. In fact, the whole sponge skeleton is nearly as rigid as soft wood, and therefore has little or no commercial value. The shape is the rounded or subspherical form as typical for the species *barbara*, and other characteristics (such as oscules) similarly correspond.

Spongia anclotea, new species

ANCLOTE SPONGE

Figs. 15 and 16

Holotype. USNM 23543. Collected by J. Storr, September 19, 1953, in 4 meters west of Dinner Point, St. Martins Reef, 8 miles west of Hammock Creek, Florida.

This species is common in the area about Anclothe Key, Florida, 28° 11' North latitude, 82° 20' West longitude, and its range extends

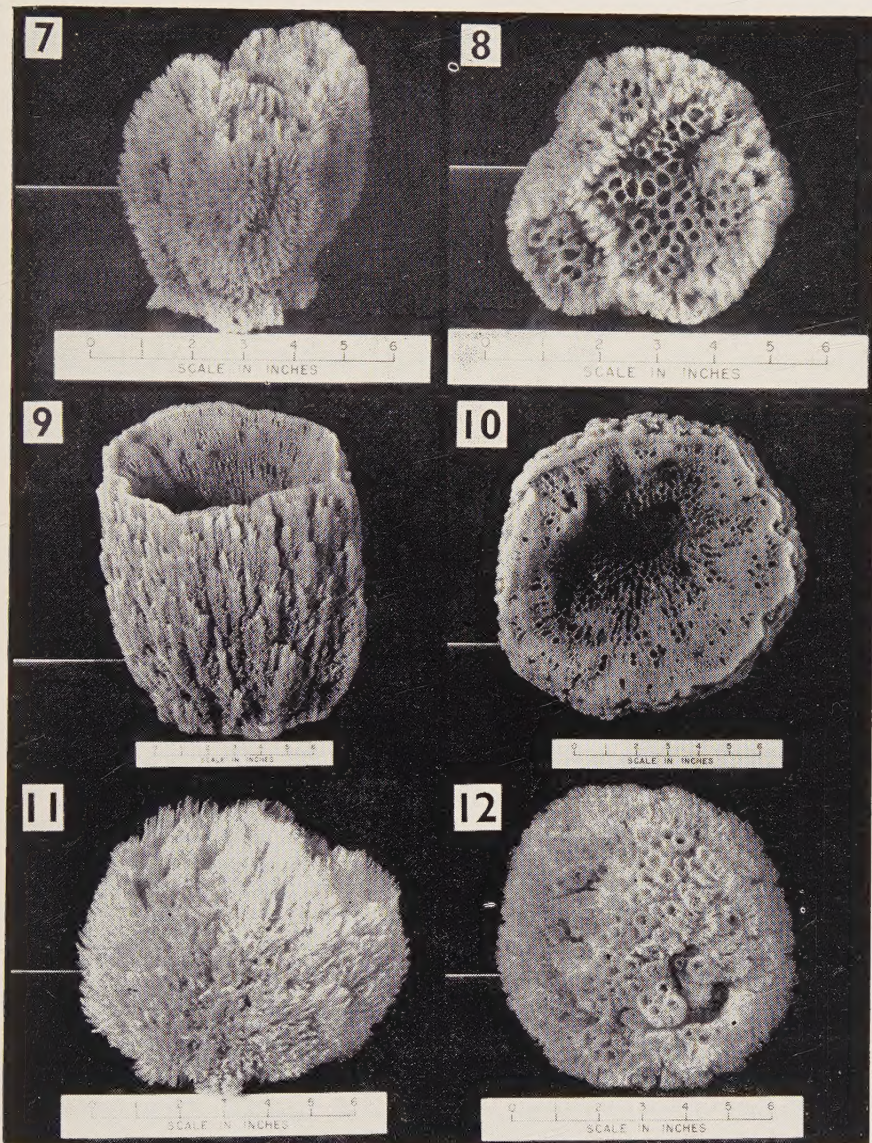


FIGURE 7. Key West grass sponge (*Spongia graminea*). FIGURE 8. Same—top view. FIGURE 9. Gulf grass sponge (*Spongia graminea* ss *tampa*). FIGURE 10. Same—top view. FIGURE 11. Grass sponge. Growth variation found in Biscayne Bay and Bahamas. FIGURE 12. Same—top view.

North to Cedar Keys. Occurrence is at depths of one to ten meters.

The shape of the "anclote" sponge is distinctive. Each specimen consists of a number (often between ten and twenty) of interconnected lobes. Each lobe is hemispherical in shape, 18 to 27 millimeters in diameter, and nearly as high above that which might be regarded as a basal mass. At the apex of each lobe is a single conspicuous oscule, seven millimeters in diameter, rarely a little larger or smaller.

The color in life is black, with the usual brownish interior. The dried skeleton is a trifle more brown than that of "yellow" sponges, and does not have the "tufted" appearance of the "yellow" sponge. Other than that, the skeleton is quite representative of the genus *Spongia*.

Spongia sterea, new species

WIRE SPONGE

Figs. 6 and 23

Holotype. USNM 23544. Collected by J. Storr, October, 1955, in 13 meters southwest of Pepperfish Key, Florida (west coast).

This sponge is common in the deeper waters west of Florida, at depths of ten to fifty meters, especially north of Cedar Keys. The junior author, in his extensive exploration, did not find this sponge east of Florida, nor in shallow water, but in July 1957 the senior author found it at a depth of only one meter, at Key Biscayne.

Spongia sterea is irregularly massive in shape, often twenty to thirty centimeters in diameter. Specimens up to 75 centimeters were reported, prior to the epidemic of 1938.

The color in life is very dark brown (sepia) or almost black, with the usual pale tan interior.

The surface is smooth or very finely conulose. The oscules are scattered, but are commoner on the upper surface; these openings are generally a centimeter (or a little less) in diameter. Exhalant canals right at the surface sometimes form a stellate pattern around an oscule.

Dried, macerated specimens of "wire" sponge are easily recognized because of their pore patterns. Instead of more numerous smaller pores, they have relatively fewer and larger skeletal pores, separated from one another by regions where dense reticulations of fibers make a flat, almost imperforate surface. The dermis may or may not contain

many additional contractile microscopic pores, but these skeletal pores are generally as much as three or four millimeters in diameter.

The fibers of the "wire" sponge are much stiffer than those of other species of *Spongia*, possibly even stiffer than those of the "hardhead," hence the vernacular name. "Wire" sponges have therefore little or no commercial value. There is another distinguishing feature, best seen by use of a microscope, but faintly distinguishable to the naked eye. Between the ascending fibers of *Spongia* there are always very numerous interconnecting secondary fibers. In *sterea*, at intervals of nearly a millimeter, there are especially straight connections at right angles to the ascending fibers, and nearly as thick as they, but not similarly supplied with debris. An effect is produced which resembles that of ladders with rungs, or of a crosshatching.

The name *sterea* is derived from the Greek ΣΤΕΡΕΑ meaning "stiff," and refers to the nature of the fibers.

Spongia graminea Hyatt, 1877

KEY GRASS SPONGE

Figs. 7 and 8

Spongia graminea Hyatt, 1877, p. 516.

This sponge is common in the area east and south of Florida, especially at depths of two to five meters; a few specimens of it may be found in deeper water, but these are small. Specimens of the "key grass" often are as large as twelve centimeters diameter, and some are as large as twenty-five centimeters diameter.

The shape of this species tends strongly toward being a truncated cone, with a base slightly smaller than the rather level upper surface. The dermis is black, and the interior is brown.

The very small pores are confined to the sides of the columnar sponge; these sides are very finely conulose. The pores lead horizontally inward to a large number of vertical cloacas or extra exhalant canals, a pattern uncommon in Recent sponges, but very common in fossil lithistid sponges as far back as the Paleozoic (Lithistid sponges have a stony-hard skeleton of interlocked lumpy siliceous spicules). These vertical canals of the "grass" sponge are nearly or quite a centimeter in diameter. The sides, affected by the cloacas, are thrown into vertical ridges and grooves, thus have a "fluted" appearance.

Each vertical cloaca, as described, leads to an oscule on the summit plateau of the sponge. There the oscules are crowded, often almost in

contact with one another, each nearly or quite a centimeter in diameter. Around each oscule is a paper thin "chimney," or collar, about a centimeter high; in it the thicker, straighter ascending fibers are conspicuous, protruding somewhat, perhaps reminding an observer of upright blades of grass. This may possibly represent the genesis of the vernacular name. It certainly forms a convenient and reliable diagnostic feature of the species *graminea*.

The top of the "key grass" sponge is sometimes concave, but never deeply concave except when foreign debris accumulates in the center, inhibiting growth there. The endosomal (interior) structures are quite representative of the genus *Spongia*.

Some very old specimens of the "key grass" variety begin to approach a spherical form as a result of much lateral growth as compared to vertical growth. This is especially the case in the Bahamas.

Spongia graminea tampa, new subspecies

GULF GRASS SPONGE

Figs. 9 and 10

Holotype. USNM 23542. Collected by J. Storr, October, 1955, in 6 meters on rocky sponge bar southwest of Pepperfish Key, Florida (west coast).

This sponge is abundant in the area west of Florida, that is to say, in the eastern Gulf of Mexico. That it is a grass sponge is evident from the presence of typical collars or chimneys around oscules, which are as crowded together, and are of the same size, as in the key grass sponge. It differs from this latter in a number of important respects. The two forms are allopatric, with possible contiguity near the Dry Tortugas, where neither is commonly present.

The subspecies *tampa* tends strongly to the shape of a vase that has a broad basis of attachment which is as wide, or nearly as wide, as the opening. The walls are upwards of six or eight centimeters in thickness. It grows to a large size so that specimens thirty centimeters in height are common; these would have nearly as great a diameter.

The color in life differs radically from the black nominate subspecies. *Tampa* is always drab or pale taupe in color. Furthermore, instead of having the conulose sides, it is smooth, even shining or glistening in appearance. These are the principal or most dependable bases for differentiation of the two varieties, because occasional un-

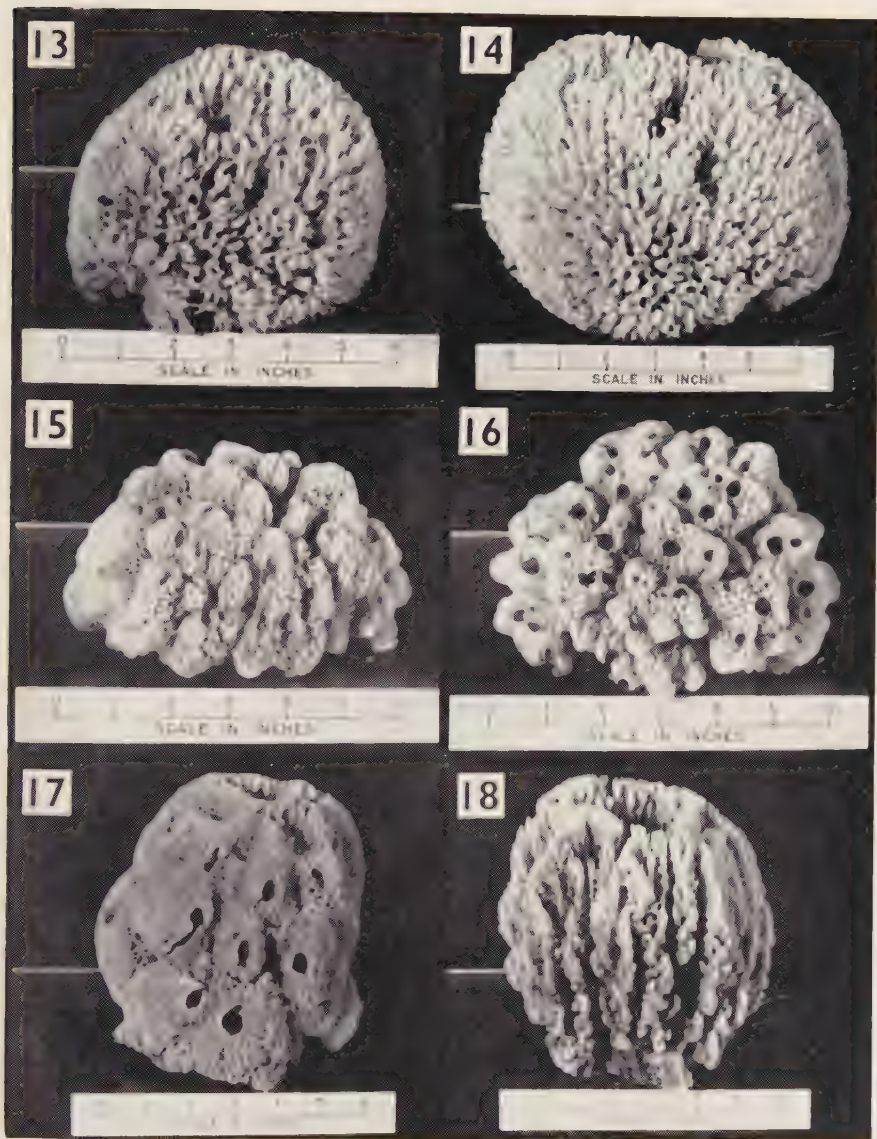


FIGURE 13. Yellow sponge (*Spongia barbara*). FIGURE 14. Yellow sponge from shallow water with long tufts. FIGURE 15. Anclote variety of yellow sponge from shallow water (*Spongia anclotea*). FIGURE 16. Same—top view. FIGURE 17. Hardhead sponge from Bahamas (*Spongia barbara dura*). FIGURE 18. Glove sponge from Florida Keys (*Spongia cheiris*).

usual specimens of the nominate subspecies have upper surfaces that are somewhat concave, and some unusual specimens of *tampa* have only slightly concave tops. These latter are found where currents are especially strong, and may lack the typical vase-shape as a result of these currents.

The outer sides of macerated, dried specimens of *tampa* are not quite the "fluted" columns of the nominate subspecies, but have a peculiar configuration. This is basically a number of lobes, three to six centimeters in diameter, but so flattened against the sides of the sponge that they are almost like imbricated cycloid scales, convexities turned upward. These sides contain scattered pores, each of which is about one millimeter in diameter.

In the deepest part of the central concavity of the "gulf grass" there are about twenty to forty collared oscules like those that are typical of all grass sponges, and equally crowded together. The rest of the concave surface is probably also chiefly exhalant, but contains openings of various sizes, not all of which are certainly oscules.

This subspecies is especially abundant near, and to the north of the city of Tampa, Florida, and the subspecific name has been selected with reference to that city.

Spongia cheiris, new species

GLOVE OR FINGER SPONGE

Figs. 18 and 24

Holotype. USNM 23545. Collected by J. Storr, September 19, 1955, in 4 meters on St. Martins Reef, Florida, west of Dinner Point (west coast).

This sponge is characteristic of shallow water, generally less than ten meters deep. The junior author found it from Key Biscayne around Southern Florida and as far north on the west coast as Cedar Keys. The senior author found it much farther north, at Alligator Harbor.

Spongia cheiris consists of one, or generally more than one, upright columns, each tapering to a rounded apex and containing one or more relatively large vertical cloacas, thus resembling the fingers of gloves. The cloacas are, in fact, so large that one may insert his finger as though into the finger of a glove. Almost always there are five or more such finger-like columns, and these are never in a straight line, but instead tend to group in a circular form, enclosing a central hollow area. It is easy to tear the columns from one another.

The outer surface of each column often bears upright longitudinal ridges, nearly a centimeter thick, with conspicuous pores along the crests of these ridges. This structure is obscure in specimens from the shallower depths (less than three meters).

"Glove" sponges are black in life, and not especially conulose.

The name *cheiris* is derived from the Greek ΧΕΙΡΙΣ, meaning "glove."

Genus *Hippiospongia* deLaubenfels, 1936

Hippiospongia deLaubenfels, 1936, p. 11.

Sponges of this genus are closely related to those of the genus *Spongia*, more closely than to any other genus except the genera *Aulena* and *Agelas*. *Hippiospongia* and *Aulena* are members of the family Spongiidae of the order Keratosida, but *Agelas* is put in the family Agelasidae of the order Poecilosclerida because, among other items, it contains proper spicules. Except for these, its specimens might be allocated to *Hippiospongia*, and some species now so allocated may actually be *Agelas* specimens in which the rather uncommon spicules were not found. *Aulena* has very peculiar flagellate chamber structure, and is rare. There are several points of distinction between *Hippiospongia* and *Spongia*.

In *Hippiospongia* there are relatively enormous subdermal spaces, meandering over the sponge, but covered in life by the dermis. The areas between these spaces are often so reduced that they are merely fascicular columns, perpendicular to the surface. The subdermal spaces are rounded in transverse sections, three to ten millimeters in diameter, most commonly four to six millimeters diameter.

In *Hippiospongia* there are no fibers of the ascending type. In fact, foreign inclusions in the fibers are so rare as to be practically non-existent. There are reports for European *Hippiospongias*, that the very young juvenile sponge appears to contain ascending fibers, but this has been compared to embryonic recapitulation of ancestral features; for example, the human embryo at one stage possesses gill slits and a tail.

In *Hippiospongia* the dermis adheres firmly to the main skeletal reticulation, whereas in *Spongia* it is always easily removed, sometimes even by merely gentle rubbing. In some species of *Hippiospongia* of the Western Pacific the dermis needs to be cut off with knife or scissors.

In *Hippiospongia* the oscules tend to be especially conspicuous. It

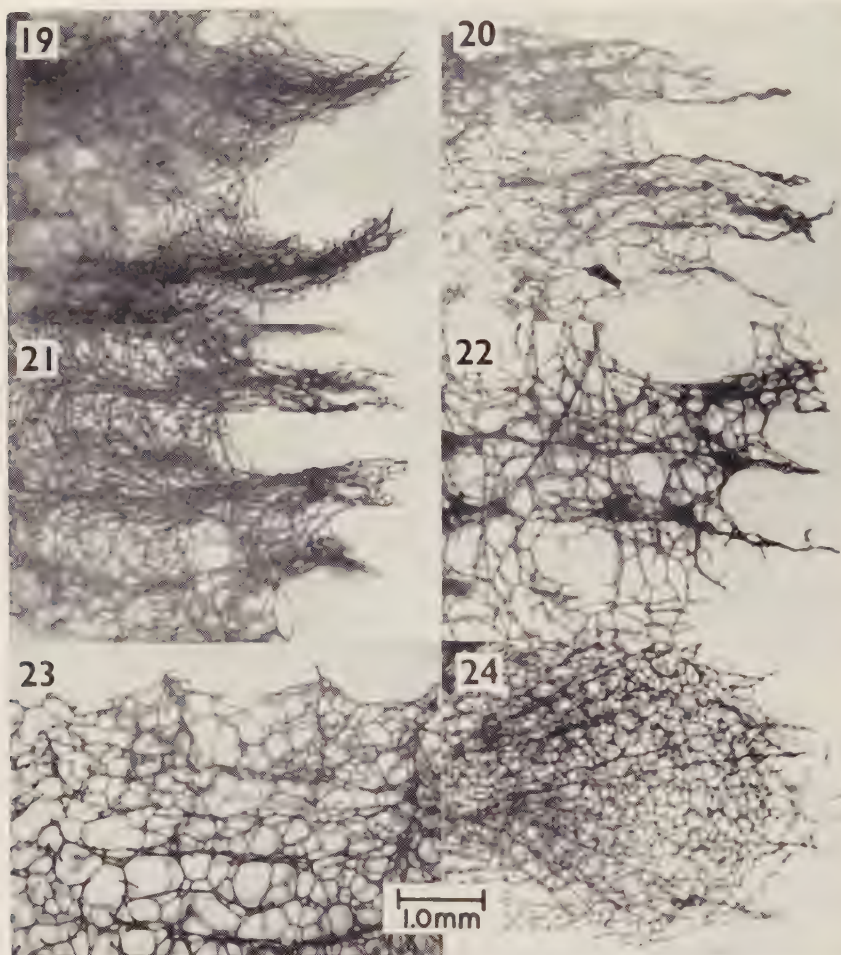


FIGURE 19. Wool sponge fibers in region of canals. Note lack of regular meshwork and the fineness of the fibers. FIGURE 20. Fibers from yellow sponge with heavy ascending or primary fibers—the principal difference between the genus *Spongia* and *Hippiospongia*. FIGURE 21. Grass sponge. Note heavier fibers and more regular meshwork. FIGURE 22. Fibers from grass sponge at four times the enlargement of figure 21. Note inclusions in primary fibers. FIGURE 23. Wire sponge. Meshwork is very regular and fibers are coarse and stiff. FIGURE 24. Cross section of edge of column of glove sponge.

is the experience of both authors that in American waters the oscules are rendered conspicuous by having dark, blackish linings to the

cloaca or canals which lead to these exits. Published accounts of sponges for other parts of the world do not make clear whether or not this is a cosmopolitan characteristic of this genus.

Hippiospongia gossypina (Duchassaing and Michelotti, 1864)

VELVET SPONGE

Spongia gossypina Duchassaing and Michelotti, 1864, p. 32.

This species was common around Florida and the West Indies prior to 1938, but was rendered all but extinct by the great epidemic. In fact, it was considered to be entirely wiped out until, in 1957, a few were reported from Cuba. It was at one time the principal commercial sponge of the Bahamas, constituting about three-fourths of the catch.

The "velvet" sponge tends to be more or less spherical, with rather conspicuous oscules on the uppermost surface.

The color in life is black, with a drab interior.

The surface is smooth or finely conulose except over the subdermal space, where it is always smooth. This space is four to six millimeters in diameter, round in cross-section, and it is covered by a tough dermis through which the microscopic pores open. This space meanders over the whole exposed surface of the sponge so that it leaves, as a residue, only columns of skeletal reticulation, like islands. The tops of these columns are flat or slightly convex, and bear the conules. The dermis is so firmly adherent to these tops that it must be cut or scraped off.

Hippiospongia lachne deLaubenfels, 1936

SHEEPSWOOL SPONGE

Figs. 1 and 2

Hippiospongia lachne deLaubenfels, 1936, p. 11.

This species has been for more than a century the most important commercial sponge of the Americas. Its specimens on the average are finer, more durable, better quality and value than those of any other New World species. It has been abundant throughout the West Indies and the vicinity of Florida, especially along the west coast of Florida.

The representative shape of *lachne* is that of a bun, round, but with greater horizontal than vertical dimensions; the top may even become

somewhat concave in the largest specimens; these may be over thirty centimeters wide and eighteen centimeters high.

The color in life is a sepia brown or extremely dark drab, not black. Against this the oscules stand out very conspicuously, because the linings of the (exhalant) cloacas are black. The oscules are generally twelve to eighteen millimeters in diameter, about six to twelve per sponge, always on the upper surface.

The surface is lumpy rather than conulose, and is smooth where the tough dermis acts as a ceiling over the subdermal space. This dermis (as noted above) is very difficult to remove. The subdermal space is a bit smaller and much less regular in outline than is the corresponding space in *gossypina*. The islands left by the subdermal meandering in *lachne* are not round columns, but have an irregular, often elongate transverse section. Furthermore, they do not terminate distally in platforms as in *gossypina* but instead taper off to pointed tufts that may be as much as two centimeters high.

The endosome of *lachne* is drab in color, with the very abundant small flagellate chambers typical of the family spongiidae.

As an appendix to the discussion of *Hippiospongia lachne*, comment should be made concerning the European (Mediterranean) sponge known colloquially as the "honeycomb" sponge. Specimens of this sort have been shipped to America and sold as "wool" sponges which they somewhat resemble.

In the dermal tufts of *lachne* some of the fibers pack together as aggregates, one to two hundred microns in diameter. Each aggregate contains ten to twenty ordinary fibers. In the "honeycomb" sponge similar aggregate columns are developed, but so much more strongly that they come to resemble single ascending fibers of the *Spongia* sort. By means of keen eyesight or a hand lens, however, the difference is at once evident. The surface of the "sheepswool" sponge is always heavily tufted; the surface of the "honeycomb" sponge is tufted only in scattered areas, leaving large smooth intervals around them.

The name "honeycomb" is suggested by the wax-like appearance of the sponge, and by the numerous openings on the upper surface. Many of these openings are about two centimeters in diameter, and six to ten centimeters apart, and clearly are oscules. Others are only three to five millimeters in diameter and only about one centimeter apart; these are probably inhalant.

It appears that no scientific name has so far been given to the "hon-

eycomb" sponge as above described. Therefore it is here proposed that it now be named.

Hippiospongia kerion, new species

HONEYCOMB SPONGE

Figs. 3 and 4

Holotype. USNM 23546. Specimen obtained from Greeks who take them in the Dodecanesi Islands in the Mediterranean Sea.

The name is derived from the Greek KHPION, meaning honeycomb.

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A NEW SPECIES OF *ACROCALANUS* (COPEPODA: CALANOIDA) FROM OFF THE SOUTHEASTERN COAST OF THE UNITED STATES¹

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United States National Museum

ABSTRACT

Acrocalanus andersoni is described and compared with other species of *Acrocalanus*. It is found in oceanic waters and does not enter the Carolinian Coastal water. *A. longicornis* is the only other Atlantic species.

INTRODUCTION

The copepod described in this paper was discovered in plankton tows made off the southern Atlantic coast of the United States from the U.S. Fish and Wildlife Service vessel THEODORE N. GILL during the general oceanographic survey of this region carried out by the Service's South Atlantic Fishery Investigations. A general account of the program of this survey is given by Anderson, Gehringer, and Cohen (1956). This is the second new copepod found in the GILL collections; the first, *Candacia paenelongimana*, occurred also in collections made in the Gulf of Mexico from the Fish and Wildlife Service vessel ALASKA (Fleminger and Bowman, 1956).

Acrocalanus andersoni, new species

Figures 1-2

Diagnosis. Female: A plump species, 1.15-1.30 mm in total length; cephalothorax about half as wide as long. Abdomen short, contained 4.0-4.3 times in cephalothorax.² Cephalothorax with moderately developed dorsal hump; no partial suture between head and first thoracic somite. Profile of head distinctive: anterior end rises vertically for about one-third the height of the cephalothorax, then slopes backward to dorsal hump. Antennae 1 long, reaching beyond caudal rami by about the last four segments. Distal part of exopod segment 3 of leg 4 with 12-13 teeth on outer margin. Male: Unknown.

Types. A female from GILL cruise 4, station 43, 32°11'N, 79°33'W, October 25, 1953, has been selected as the holotype and given U.S. N.M. no. 100906. 83 paratypes from various stations of GILL cruises

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²Cephalothorax measured dorsally from anterior margin of head to posterior margin of produced thoracic somite 5. Abdomen measured dorsally from anterior margin of genital somite to posterior margin of right caudal ramus.

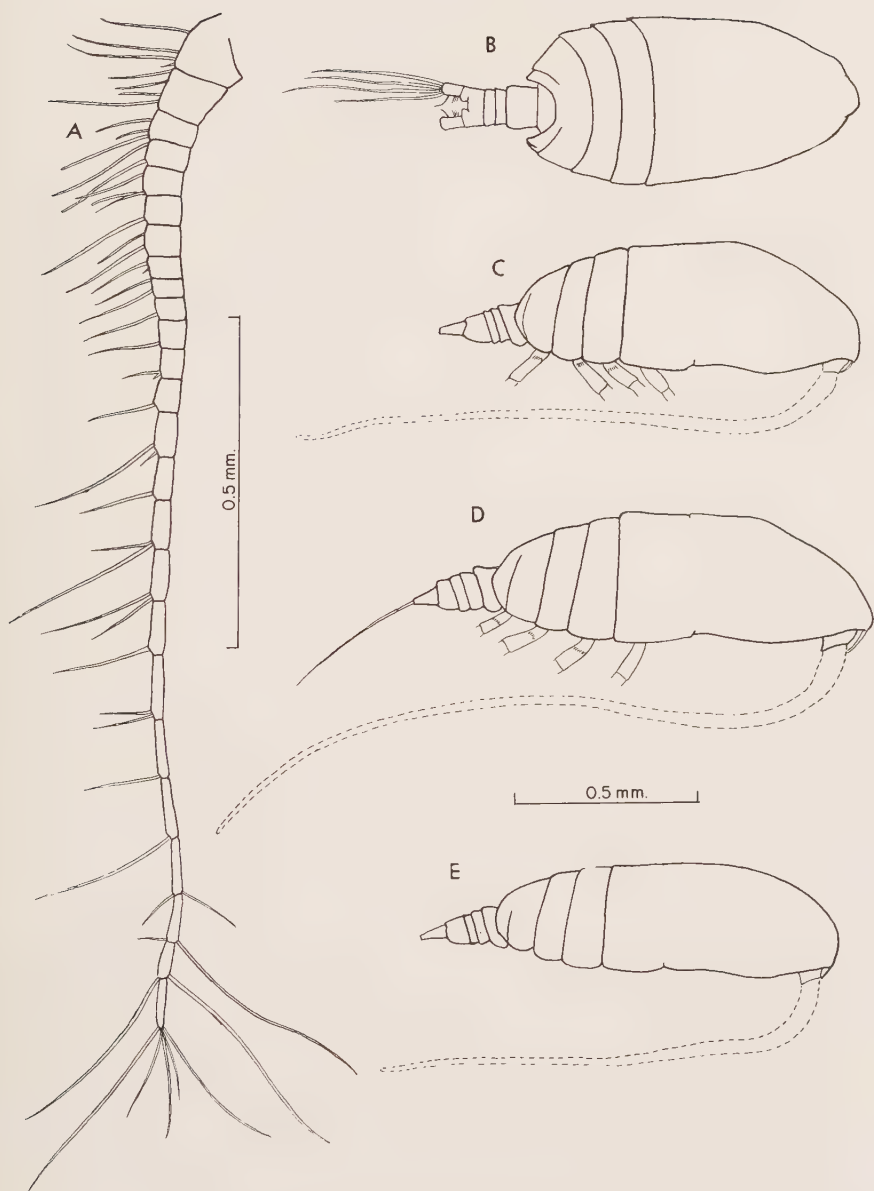


FIGURE 1. A-C, *Acrocalanus andersoni*, new species. A-B, Holotype, GILL cruise 4, station 43; C, GILL cruise 2, station 18. A, Antenna 1, B, Dorsal view. C, Lateral view. D, *Acrocalanus longicornis* Giesbrecht, GILL cruise 1, station 26, lateral view. E, *Acrocalanus gracilis* Giesbrecht, CARNEGIE station 99 ($4^{\circ}22'N$, $176^{\circ}22'W$), lateral view. B-E, same scale.

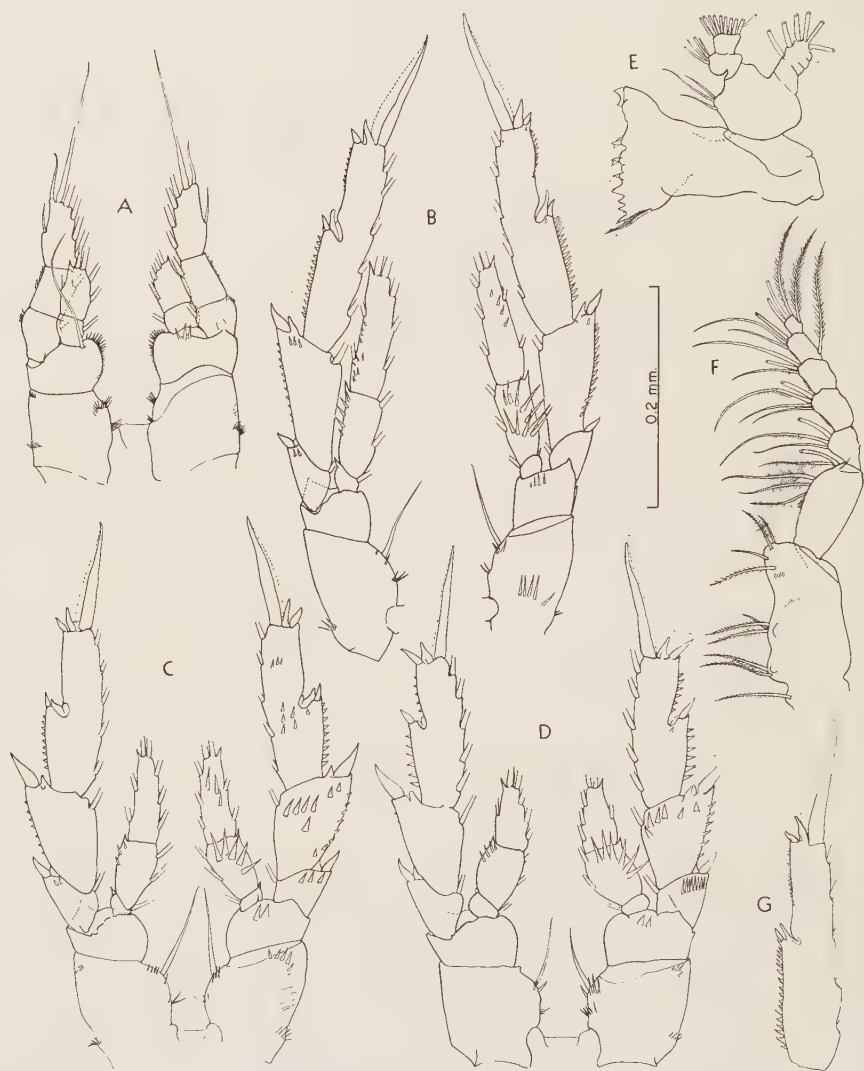


FIGURE 2. A-F, *Acrocalanus andersoni*, new species. A, C-F, GILL cruise 2, station 18; B, GILL cruise 2, station 62. Swimming legs drawn to show anterior surface on left, posterior surface on right. A, Leg 1. B, Leg 4. C, Leg 3. D, Leg 2. E, Mandible. F, Maxilliped. G, *Acrocalanus longicornis* Giesbrecht, GILL cruise 1, station 25, exopod segment 3 of leg 4, posterior surface.

1-4 have also been deposited in the U. S. National Museum.

It is a pleasure to name the new copepod in honor of William W. Anderson, Chief, South Atlantic Fisheries Investigations, who made

aliquot samples of the GILL plankton collections available to me.

Distribution. The distribution of *A. andersoni* determined from GILL cruises 1-4 (10 Feb.-10 March, 17 April-14 May, 16 July-12 Aug., and 17 Oct.-12 Nov., 1953) is shown in Fig. 3. Data for the four cruises have been combined, since the infrequent occurrence of the new species makes it difficult to generalize about its distribution from the findings of one cruise. And too few specimens were obtained to present a reliable quantitative picture of the distribution. It is apparent that *A. andersoni* is an inhabitant of oceanic waters, and its shoreward distribution is limited by the cooler and less saline Carolinian Coastal water (Bumpus and Pierce, 1955). *A. longicornis* has a similar distribution, and the two species were often taken in the same net tow.

Discussion. Of the 5 species of *Acrocalanus* currently recognized, *A. gibber* Giesbrecht, *A. gracilis* Giesbrecht and *A. longicornis* Giesbrecht are most similar to *A. andersoni*. *A. gracilis* is a slimmer species with a relatively longer abdomen contained 3.6-4.0 times in the cephalothorax. Seen laterally (Fig. 1, E) the cephalothorax is evenly rounded without any dorsal hump, and the head is slightly produced. Antennae 1 are shorter than in *A. andersoni*, reaching only slightly beyond the caudal rami. *A. longicornis* is also slimmer than *A. andersoni*, but more thickset than *A. gracilis*. Its forehead is much lower than that of *A. andersoni* (compare Figs. 1,C and 1,D). The dorsal hump is pronounced, and a partial suture between the head and thoracic somite 1 is usually, though not always, present dorsally. Its abdomen is contained 3.7-4.3 times in the cephalothorax. As its name implies, antennae 1 are very long, reaching beyond the caudal rami by 5-6 segments. I have not seen specimens of *A. gibber*, since the specimens in the U.S. National Museum identified as *A. gibber* by C. B. Wilson are *A. gracilis* and *A. longicornis*. It differs from *A. andersoni* by its smaller size (0.74-1.0 mm), the presence of a partial suture dorsally between the head and first thoracic somite, and the shorter antennae which reach to the middle of the caudal rami or beyond the rami by 1-3 segments.

The species of *Acrocalanus* are most conveniently distinguished by the shape of the cephalothorax in lateral view. Good illustrations of this character for *gibber*, *gracilis*, *longicornis*, and *monachus* are given by Giesbrecht (1892, pl. 6, figs. 25, 26, 27, 32), Wolfenden (1905, pl. 97, figs. 6-9), and Mori (1937, pl. 12, figs. 1, 6, 8, 10); while Sewell (1929, text-figs. 31, 32, 33) provides illustrations for *gibber*, *gracilis*, and *longicornis*. The cephalothorax of *A. inermis*

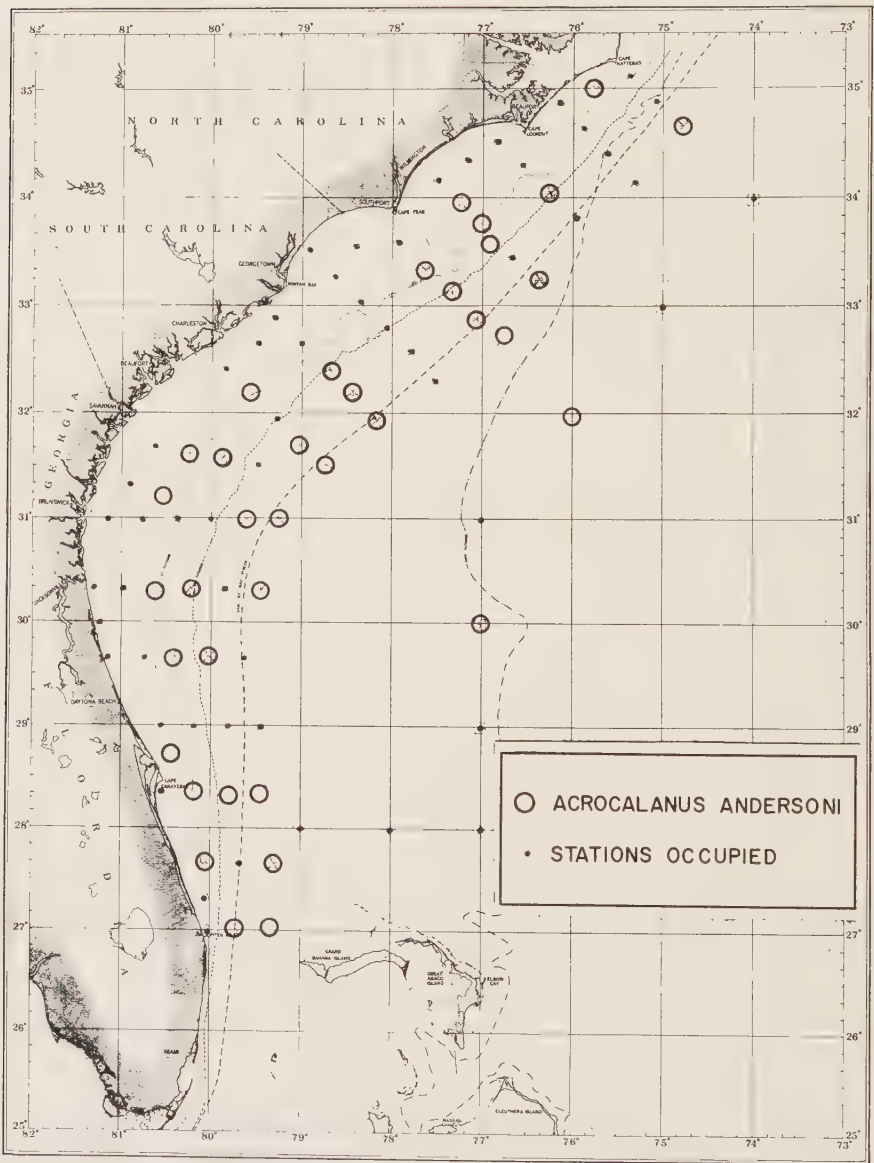


FIGURE 3. Distribution of *Acrocalanus andersoni*, new species, T. N. GILL cruises 1-4 combined.

Sewell (1912) has a shape similar to that of *A. andersoni*, but *A. inermis* is easily separated from other species of *Acrocalanus* by its

short antennae 1, long abdomen, and the absence of teeth on the outer margins of the exopods of the swimming legs.

The mouthparts are of little value in discriminating between species of *Acrocalanus*. I have compared the mouthparts of *A. gracilis*, *A. longicornis*, and *A. andersoni* and have been unable to find any characters diagnostic on the specific level. Illustrations of the mandible and maxilliped of *A. andersoni* are given here (Fig. 1, E-F).

Likewise, the swimming legs of *A. gracilis* and *A. andersoni* are identical in all details. In *A. longicornis*, however, the distal part of exopod segment 3 of leg 4 has 15-20 fine teeth on the lateral margin (Fig. 1, G), while an *A. gracilis* and *A. andersoni* there are 11-15 coarser teeth.

The details of the surface armature of the swimming legs of *A. andersoni* are shown in Fig. 1, A-D. In each case the anterior surface is shown on the left, and the posterior surface of the same leg is shown on the right. In most published drawings of species of *Acrocalanus*, only one surface, usually the posterior, is shown, with the result that at least part of the armature of the other surface is often overlooked. The surface armature of legs 1-4 of *A. gracilis* is identical in all respects with that of *A. andersoni*. The surface armature of the legs of *A. longicornis* is also identical except for the addition of a row of spines on the posterior surface of the distal part of exopod segment 3 of leg 2; these spines are shown in the illustrations of Wolfenden (1911, pl. 97, fig. 12) and Sewell (1929, text-fig. 33d).

A. andersoni is the second Atlantic species of *Acrocalanus*. Wilson (1950) reported *A. gracilis* from ALBATROSS station 13 in the South Atlantic (48°37'S, 65°46'W), but an examination of the records and collections of the U. S. National Museum proved this location to be in error; the specimens in question were from the substation of Sept. 5, 1899 (9°26'N, 137°49'W) listed in Townsend's records (1901, p. 485) below Agassiz serial no. 13 (dredging station 3683).

A. gibber has been reported from the Mediterranean once, by Thompson (1900). Thompson's material was collected by attaching nets to taps leading to the ship's sea water storage tanks. As Sewell (1938, p. 428) has pointed out, organisms collected from the taps may have been pumped into the tanks much earlier; hence it is possible that the specimens of *A. gibber* obtained from the taps at Mediterranean stations were pumped into the tanks while the ships were passing through the Red Sea or Suez Canal. Gurney (1927) found *A. gibber* to be common in the southern part of the Suez Canal; in the

northern part only small numbers of immature specimens were present, and it was absent from the collection made at Port Said.

A. longicornis remains the only species of the genus definitely known to occur in both the Atlantic and Indo-Pacific. The records of its distribution are fully summarized by Verwoort (1946).

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STUDIES OF THE DISTRIBUTION AND FEEDING HABITS OF SOME OYSTER PREDATORS IN ALLIGATOR HARBOR, FLORIDA¹

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ABSTRACT

Observations were made on the distribution in Alligator Harbor and ability to kill oysters of *Busycon contrarium* Conrad, *Melongena corona* Gmelin, *Murex pomum* Gmelin, *Thais haemastoma* Conrad, *Pleuroploca gigantea* Keiner, *Menippe mercenaria* Say and *Callinectes sapidus* Rathbun. *B. contrarium* were numerous and very destructive to oysters, killing them mainly by chipping the edges of the shell, also by forcing the oyster's valves apart. *M. corona* feed by inserting the proboscis in the relaxed and open oyster. They were sometimes locally abundant but were not established as a serious oyster predator. *M. pomum* were abundant, but only subtidally below the intertidal oyster reefs, and killed available oysters by drilling the shell. *T. haemastoma* were very scarce and of no importance as an oyster enemy in the area. *P. gigantea*, sporadic in occurrence, did not feed on oysters. *M. mercenaria* and other xanthid crabs were very abundant and destroyed many oysters by breaking the shells. *C. sapidus* were abundant. They kill healthy small oysters, but only weakened large oysters.

INTRODUCTION

Predation is one of the limiting factors in oyster production. This is especially true in areas of high salinity where many predators abound (cf. Gunter, 1955). Atlantic Seaboard oyster growers have to contend with only two or three serious oyster predators, but oysters in high salinity areas in Florida and elsewhere in the Gulf of Mexico region are plagued with many species of predators.

This study concerns several predators in an area of relatively high salinity in Alligator Harbor, Franklin County, on the northwest coast of Florida, site of the marine laboratory of the Oceanographic Institute, Florida State University. This study was used in part in the master's thesis of the junior author at the Oceanographic Institute, Florida State University. The authors wish to thank Drs. S. H. Hopkins, The Agricultural and Mechanical College of Texas, and Gordon Gunter, Gulf Coast Research Laboratory, for review and suggestions.

Observations were made on five gastropod mollusks and two decapod crustaceans. The studies involved field observations on predator abundance and damage to oysters. Experiments were conducted in which the predator was placed in a cage with oysters; these were

¹Contribution number 100, Oceanographic Institute, Florida State University.

examined periodically for mortality. This work was done in connection with another study of oysters in the intertidal region of Alligator Harbor (Nichy and Menzel—in preparation).

LOCALITY

Figure 1 shows the general outline of Alligator Harbor. Dense oyster reefs are found in this area as indicated by the stippling around the marsh at the east end and also the small islands and shore to the north. All of the oyster reefs are intertidal. Experiments were conducted in the lagoon of an atoll-shaped island known locally as "Sting-A-Ree Island." The island is low and flat, approximately 75 cm above low water, and is covered with a dense growth of *Spartina*. The only passage into the lagoon at low tide is located on the northwest side, and is approximately 6 meters wide. Tides above mean high water flood the marsh area with several centimeters of water. The bottom structure of the lagoon varies from firm sand in the central portion to soft mud along the shorelines, which are interspersed with shell flats. The bottom is flat and is approximately 18 centimeters below mean low water.

Approximately 200 meters northwest of Sting-A-Ree Island is a chain of six small islands, with narrow channels in between. These islands, called "Mutsure Jima" here, are fringed by dense oyster reefs.

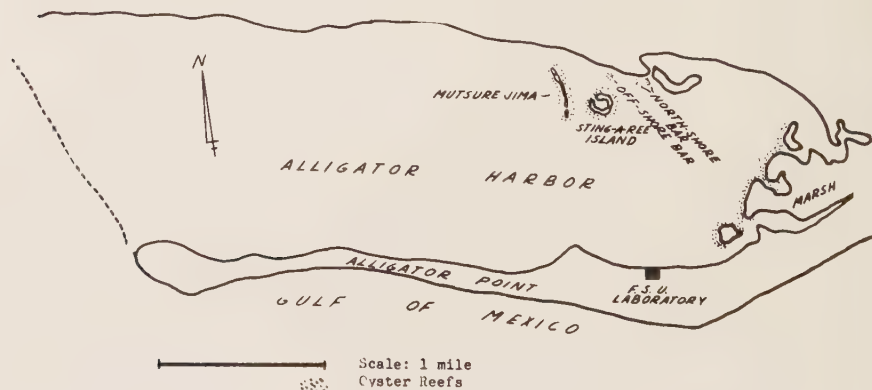


FIGURE 1. Outline of Alligator Harbor and location of oyster reefs.

Other oyster bars are found along the salt marshes in the easterly portion of the harbor and extend into the drainage channels of the marsh. The only other bars in the harbor are two small separated reefs along the north shore, northeast from Sting-A-Ree Island, referred to here as "Off-Shore Bar" and "North-Shore Bar" (Figure 1).

HYDROGRAPHY

The hydrography of Alligator Harbor has been described by Olson (1955).

The temperature recorded in the lagoon ranged from 20.0°C. to 34.5°C. (Table 1) during the time of the observations, 26 March 1955 to 22 October 1955 and was usually one to three degrees higher during the day than concurrent readings in the harbor.

Alligator Harbor is a shallow bay, averaging less than 2 meters deep. It has been called a neutral estuary because no streams flow into it. The salinity (Table 1) is high and fairly constant.

METHODS

Experimental. Known and suspected predators were maintained in cages in the lagoon to determine their respective feeding rates and to observe the methods which they used to open oysters. The following animals were kept in cages: two lightning whelks, *Busycon contrarium* Conrad, measuring 279 mm and 295 mm; two crown conchs, *Melongena corona* Gmelin, 94 mm and 105 mm; two southern oyster drills, *Thais haemastoma* Conrad, 47 mm and 49 mm; two apple murexes, *Murex pomum* Gmelin, 43 mm and 47 mm; one stone crab, *Menippe mercenaria* Say, 80 mm in width; two horse conchs, *Pleuroploca gigantea* Keiner, ca. 250 mm each; and blue crabs, *Callinectes sapidus* Rathbun of an average size of 135 mm in width.

Each animal was kept in a separate cage. The two *Busycon contrarium* were kept in cages made of ½ inch mesh hardware cloth, 50 cm wide, 75 cm long and 25 cm high. Approximately half of the area of the bottom was removed in the central portion to allow them to bury themselves, because this is considered necessary for normal activities. The blue crabs, stone crab, and horse conchs were kept in wire cages of the same size except that the bottom was intact. The crown conchs, oyster drills and murexes were contained in smaller wire cages, 40 cm long, 35 cm wide and 15 cm high. At first the crown conchs were placed in cages with half of the bottom removed, like the *B. contrarium* cages, but after the first three weeks they were moved to enclosed cages because they continually burrowed under the wire half of the bottom. The fact that they were not allowed to bury themselves as they normally do was partially compensated for by adding sand to the inside of the cages.

The cages were first placed on a shelly area well within the lagoon,

TABLE 1

TEMPERATURE AND SALINITY FROM THE LAGOON, STING-A-REE ISLAND,
IN ALLIGATOR HARBOR, FROM 26 MARCH TO 22 OCTOBER 1955.

Date		Temperature (°C.)	Salinity (‰)
March	26	22.5	32.5
April	5	20.5	33.0
	12	23.5	32.5
	16	26.0	33.0
	20	25.0	33.5
	30	24.0	35.0
May	10	24.5	34.5
	17	25.0	34.0
	22	26.0	34.0
	29	32.0	34.5
June	4	31.0	35.0
	11	30.5	36.0
	18	30.0	35.5
	25	32.5	35.0
July	5	32.5	35.0
	9	33.0	34.5
	16	33.5	34.5
	23	34.5	34.5
	30	34.0	34.5
Aug.	6	34.0	34.5
	12	34.0	34.0
	20	34.0	33.5
	28	33.5	33.0
Sept.	4	29.0	32.5
	10	29.0	33.0
	17	30.0	33.0
	23	33.5	33.0
Oct.	1	30.5	33.0
	8	29.0	—
	15	22.5	—
	22	22.0	—

but silting became a problem there. Consequently they were moved to an area near the opening of the lagoon. Some silting occurred, but its effect was reduced by raising the cages on built-up sand and shell.

All of the oysters placed in the cages were culled to singles, except for a small cluster that was placed in each apple murex cage, since it was noted that these gastropods were often found in clusters of oysters that had broken off the reef.

Field Observations. Enumeration of predators were made by vari-

ous methods, including transects and tagging. Transects were made by stretching a measured line perpendicular to and below the reef and counts were made in an area on either side of the line as far as the outstretched arms could reach from a kneeling position. This was approximately the width of one meter. This method was applicable to such species as *Murex pomum* which do not move offshore with the receding tide, but remain attached to some substrate.

Busycon contrarium required a different counting procedure because the conchs were often buried near the reefs, sometimes out of sight, or had moved away from the reef during low tide, especially during the day. Therefore counts had to be made at night or at dawn while they were still feeding on or near the reef. The results of the counts are given as the number of busycons per unit area of oyster reef. Counts were made by rowing along the reefs when possible or by walking along the reefs. *B. contrarium* were tagged primarily for migratory studies. At first tagging was done by painting a number on the dorsal surface of the shell, but another method was soon substituted because of the difficulty of drying shells on certain days. Plastic tags were made and attached to the shell near the outer lip margin in the posterior region. Two holes were drilled in this region and the tag attached with a fine nickel chrome wire with the splice on the outside. Two busycons were kept caged for two weeks after tagging to see if any deleterious effects resulted from the tags. It was found that feeding was not impaired and they were released.

The tagged animals were captured and released at the following places: the lagoon, Off-Shore Bar, Northshore Bar, Mutsure Jima and pier of the Florida State University Marine Laboratory (Figure 1). Sixty-six whelks were tagged during the four week period from mid-August to mid-September.

Melongena corona, the crown conch, because of the small numbers, were counted by pacing along the reefs during low tides, making a total count of the number present, and giving the results as the number found per unit area of oyster reef. *Murex pomum* were counted below certain reefs and the density is given as the number present per square meter in these areas.

Attempts to count xanthid crabs were unsuccessful because of their burrowing habits and no estimate was made of the numbers of blue crabs, *Callinectes sapidus*. The Southern oyster drill, *Thais haemastoma*, was very rare in Alligator Harbor, in fact a diligent search had to be made to find specimens to use in the cage experi-

ments. *Pleuroploca gigantea* was found at infrequent intervals and no attempt was made to estimate their abundance per unit area.

RESULTS AND DISCUSSION

Busycon contrarium, lightning whelk

Busycon contrarium is the only species of *Busycon* that is found abundantly in the harbor. Three *B. canaliculatum* L., the channeled whelk, were found in October near the oyster reefs at Mutsure Jima, but prior to that time none had been observed. No species but *B. contrarium* was found in the lagoon in Sting-A-Ree Island, where the majority of the observations were made.

The average size of *B. contrarium* measured and tagged during the experiment was 22.9 cm in height. The largest busycon tagged measured 31.8 cm; the smallest one tagged measured 8.8 cm. Since small busycons were not tagged because of the difficulty in finding them, the actual average size in the population would be less.

The distribution of *Busycon contrarium* in the harbor is not fully known. Primarily they have been found close to oyster reefs or wherever oysters are present. They are often found on the sandy-mud flats of the harbor and have been observed feeding on several species of mollusks that live in the bottom. The whelks are efficient "diggers" for clams. Counts made on and near oyster reefs throughout the period of the study showed an average of one per 25 square meters. Information from tagging indicated that the population is probably larger than estimated by direct count. Weekly checks were made for a period of 20 weeks and the number of times any one of the tagged busycons was found was comparatively low. The highest number of times any one of them was found was 7; the majority of them was found only once and some were not found at all. Most returns were from the lagoon in Sting-A-Ree Island, because many of the whelks which had burrowed could be found by poking in the bottom in the enclosed area. It is common to find whelks partially or completely buried. Thus it is believed that a direct count will never give the true population number.

Tagged whelks were never found in any area except where they were released and it is assumed that there is little migration. Eight of the sixty-six tagged snails were found dead during the period of observations, and it is not unlikely that more of them died and were not found. It is not considered that tagging was responsible for the deaths because dead untagged snails were found at the same time and observations had shown that the feeding was not hindered by the tags.

When the water temperatures were 20 to 25°C., the busycons were observed feeding on the reefs and at all times of the day, and often feeding in the middle of the lagoon. When the temperature rose to near 30°C., feeding during the daytime ceased, and in the lagoon the whelks were almost invariably found buried, at all stages of the tide. Although the whelks were inactive during the daytime when the temperatures were near 30°C., oyster mortality caused by them still occurred for they are nocturnal in their feeding habits during periods of high temperatures. During the night visits, an unusually large number of the snails were found feeding in the lagoon and on the other reefs in the harbor.

TABLE 2

COMPARISON OF RATE OF OYSTER MORTALITY
CAUSED BY *Busycon contrarium* WITH TEMPERATURE

Average Temperature	Date	Weekly Average Mortality	Number of Exams
Less than 32° C.	26 March - 18 June	18	6
Greater than 32° C.	25 June - 4 Sept.	11	11
Less than* 32° C.	10 Sept. - 22 Oct	24	8

*Temperature on 23 September 33.5

There was a change in the feeding rate of the busycons when the temperature became high. Some suggestion of the influence of temperature may be seen in Table 2, which presents the average number of oysters killed when the temperature was below 32°C. (30 April to 18 June and 10 September to 22 October) and when the temperature was above 32°C. (25 June to 4 September). The average number of oysters killed weekly when the temperature was below 32°C. was 21, whereas 11 oysters were killed per week when the temperature was above 32°C.

The chipping of the edges of mollusks' shells until the proboscis of the busycon could be inserted has been described by Colton (1908), Clench (1939), Magalhaes (1948) and Carriker (1951). In the present study it was found that the majority of oysters killed had the edges of the bill planed or chipped by the busycons. Another method employed to open oysters was by force. This was observed in detail on one occasion.

An oyster was placed under a snail in shallow water, and after a period of about 4 minutes the foot of the busycon enveloped the entire oyster. The right valve of the oyster was against the flat of the busycon's foot and the bill of the oyster was pointed upwards. The edge of the busycon's foot extended slightly over the bill of the oyster. After manipulation with the foot, the part of the foot that extended over the posterior ventral portion of the bill of the oyster was retracted, leaving an area along the rim of the oyster's valve exposed, and the outer edge of the shell of the busycon was brought down against this exposed area. At this time the junior author inserted his index finger between the lip of the busycon shell and the oyster's bill as close as possible to the point of contact of their shells so that pressure exerted by the busycon on the valve of the oyster could be felt. The busycon periodically raised and lowered the outer lip of its shell about 3 mm, pressing down at various places along the oyster's bill. The pressure was estimated to be about 1 to 2 pounds. This process was repeated four or five times, and then what seemed a satisfactory point was found. Suddenly, in comparison to the previous sluggish movements, the lip was brought down with extreme pressure. Within 2 seconds after this surge of pressure, the oyster opened with a sucking pop. (The author's finger had been removed before this occurred). Most of the oyster meat was devoured within two minutes except for some strands of muscle and parts of the gills that had floated outside the shell. The size of the oyster was 70 mm by 43 mm, and the length of the busycon was 30.5 cm (12 inches). Observations on the feeding habits of *B. contrarium* in an aquarium were attempted but they were inconclusive.

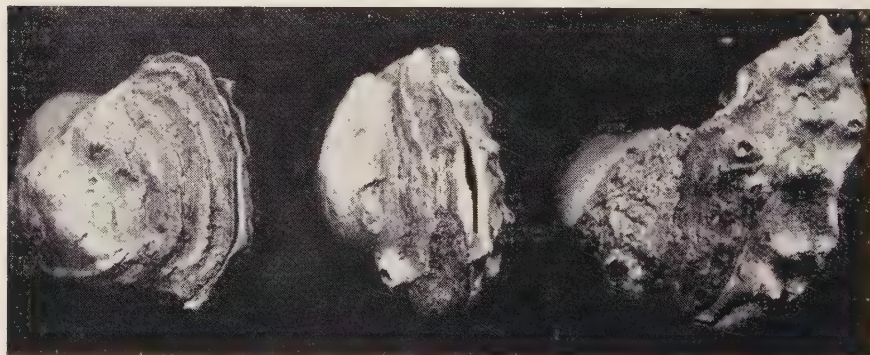


FIGURE 2. Oysters killed by the lightning whelk, *Busycon contrarium*. The edges of the bill of the oysters were chipped or planed by the whelk.

Magalhaes (1948) and Carriker (1951) have questioned the use of force by busycons to open bivalves. The use of force by *B. contrarium* as a means of opening oysters was observed repeatedly in the present study. This species is much larger than those used by other investigators. Galtsoff (1952) found that spawning oysters are weak and states that a pull of 11 to 22 pounds will open an oyster within 15-60 minutes. There is a possibility that the oysters themselves are much "weaker" in the southern waters than in more northern areas. The senior author has noted the relative ease in shucking oysters from the Gulf of Mexico when compared with those from the Chesapeake Bay. At various times when a busycon was found opening an oyster, and when it was possible to grasp both firmly, it was found that some-



FIGURE 3. Oysters killed by the lightning whelk, *Busycon contrarium*. The oysters were killed by force. Often the force was so great that the oyster valve was broken, as shown in the photograph.

TABLE 3

MORTALITY OF CAGED OYSTERS CAUSED BY *Busycon contrarium*,
PLACED IN THE CAGES 30 APRIL 1955

Date	Cage 1			Cage 2		
	No. Pres.	No. Dead	% Dead	No. Pres.	No. Dead	% Dead
May	10	25	0	25	0	0.0
	17	25	2	25	5	20.0
	22	25	10	25	9	36.0
	29	25	12	25	9	36.0
June	4	25	13	25	10	40.0
	11	25	14	25	9	36.0
	18	25	12	25	8	32.0
	25	25	5	25	8	32.0
July	5	25	10	25	9	36.0
	9	25	9	25	5	20.5
	16	25	7	25	8	32.0
	23	25	11	25	3	12.0
	30	25	14	25	1	4.0
Aug.	6	25	0	25	6	24.0
	12	25	0	25	0	0.0
	20	25	5	25	10	40.0
	28	25	0	25	0	0.0
Sept.	4	25	9	25	8	32.0
	10	25	12	25	10	40.0
	17	25	4	25	12	48.0
	23	25	16	25	10	40.0
Oct.	1	25	20	25	12	48.0
	8	25	20	25	10	40.0
	15	25	20	25	8	32.0
	22	25	13	25	7	28.0
Totals		238		187		

times they could not be pulled apart for a few seconds, no matter how much strength was applied. Some of them, though, were separated easily.

The majority of the oysters killed in the experimental cages had the bills planed back as shown in the photograph in Figure 2. Oysters which were typical of those believed to have been opened by force are shown in Figure 3. (The one which was observed being opened by force is shown in the upper left corner.) Busycons found feeding were often observed to have the oyster in such a position that the bill was being forced up against the outer lip of the busycon's shell, and in such cases the bill was found to be chipped or broken. The complete process

was never witnessed and can only be deduced. The observation of the chipping of the oyster's bill is in agreement with other authors who have reported on this subject. (Cf. Magalhaes, 1948 and Carriker, 1951).

Two busycons measuring 27.9 cm and 29.5 cm in length were caged in the lagoon for 24 weeks. Counting only those oysters with damaged shells, the busycons killed a total of 408 oysters during this period (Table 3). The average number killed per week was 10 for one whelk and 7 for the other. Results of the first week were excluded to allow the busycons to become adjusted to being caged. The maximum number killed during one week by one busycon was 20 oysters. This same animal killed 20 oysters per week for three consecutive weeks. Oyster consumption of the two caged busycons was significantly higher than Carriker's (1951) results on the feeding rates of *Busycon canaliculatum* and *B. carica* Gmelin. The difference is due probably to the larger size of the *B. contrarium* used in the present investigation.

Melongena corona, crown conch

Crown conchs were found on the oyster reefs in the harbor in varying abundance. In the easterly portion of the harbor, it was found that *Melongena corona* were absent from many of the reefs. These reefs were seemingly similar to those near the lagoon in Sting-A-Ree Island, where crown conchs were relatively abundant. In estimating the population of crown conchs, only those near the lagoon were considered. It was estimated that there was approximately one crown conch per 200 square meters or 0.005 per square meter. This estimate, although approximate, indicated a small population of *M. corona* in the harbor. Hathaway (1957) found crown conchs to be much more abundant in Indian Lagoon, Apalachicola Bay, Florida.

The crown conchs were found buried at all levels of an oyster reef and also in the areas adjacent to the lower edge of the reefs. Their abundance in the deeper waters of the harbor is not known, but they are believed to be concentrated primarily in the proximity of the oyster reefs. Hathaway (1957) found that the smaller crown conchs are in the deeper waters of the flats adjacent to the oyster reefs and only the larger individuals occur on the reefs.

From the beginning of the observations until the end of July, crown conchs were found spawning. Perry and Schwengel (1955) state that *M. corona* spawn from January to June. Since we made no observations before 19 March, it is not possible to determine when spawning began in the harbor. It is known, however, that spawning did con-

tinue until late July, for one of the caged animals laid a string of egg cases on one of the oysters during the week before the 30 July examination. During the period when they were spawning, crown conchs were found on the shell flats in the lagoon, in the middle of the lagoon, and on an oyster reef near the entrance to the lagoon. Egg capsules of *M. corona* were also found in these areas. After cessation of spawning, they were invariably found on the oyster reefs, and few were observed moving about.

M. corona was rarely observed feeding on oysters in the harbor. The method used to gain entrance into the oyster presented a perplexing problem at first for no mark or damage was ever found on the valves of the opened oysters and there was no indication that force had been used. At low tide it was sometimes observed that oysters had closed the shells over the proboscis of the crown conchs. One *M. corona* that was found eating an oyster had its proboscis inserted between the valves so deeply that it was possible to clamp the proboscis by pressure on the valves of the oyster and thus prevent the snail from retracting it. The means by which the proboscis is inserted into an oyster was observed through aquarium studies by the junior author and the account was given in Gunter and Menzel (1957).

During the time (10 May to 22 October) when *M. corona* were caged, only three oysters were found dead in the cages. On 10 May, two *M. corona* were placed in separate cages with oysters. The two original crown conchs were replaced with two others on 16 July; no dead oysters had been found up to this time. The last two remained caged until 22 October and three oysters were found dead in one cage and none died in the other during this period. It was not possible to relate mortality to predation by the crown conch.

Many shell books describe *Melongena corona* as an extremely predacious gastropod and Moore (1897) considered that it may be an important predator on oysters. *M. corona* are sometimes numerous on the oyster reefs in restricted areas. The results obtained from the cage studies with oysters are inconclusive, but it is doubtful if this species is an important oyster predator in Alligator Harbor. Hathaway (1957) came to the same conclusion in his study in the region of Apalachicola Bay, Florida. They undoubtedly kill some oysters on the reefs and have been observed feeding on dead fish and crabs in Alligator Harbor.

Murex pomum, apple murex

Murex pomum is not evenly distributed throughout the harbor, but

occupies a specific bottom type below the intertidal oyster reefs. The largest numbers of apple murexes were found where the area adjacent to the lower edge of the reef contained an abundance of shell debris. Reefs that lacked this debris were found to be devoid of this snail. Many of the reefs, especially in the small inlets of the marshes, where they were protected from wave action, had no shells below the intertidal reef and no *M. pomum* were found.

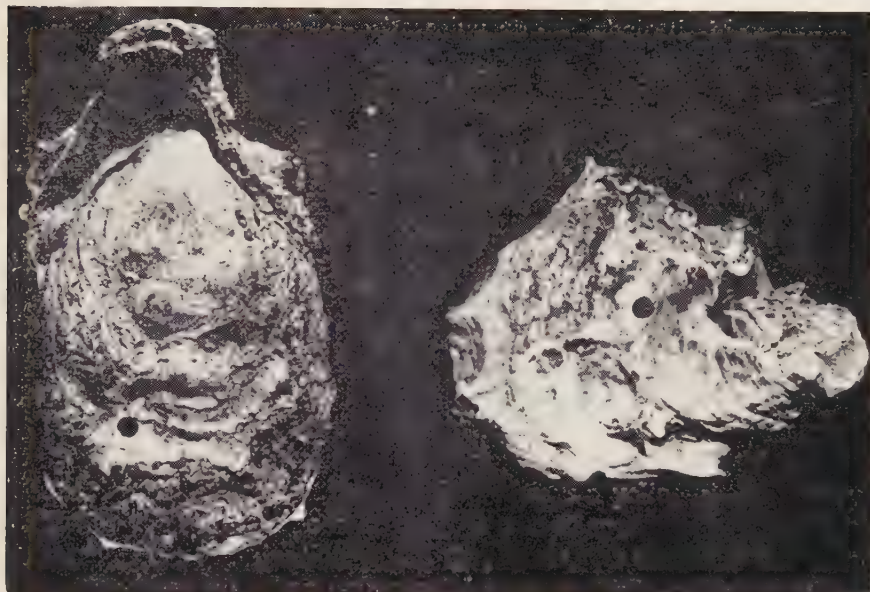


FIGURE 4. Oysters killed by the apple murex, *Murex pomum*. In one oyster the hole was drilled in the right valve, in the other the left valve.

In regions where they were common, the largest numbers were concentrated from slightly below to approximately 50 cm below mean low water. None were ever found on the intertidal reefs. They were found in significant numbers as far as 10 meters from the reef, but the abundance in the deeper waters of the harbor is not known. However, random dredge samples in the deeper areas, where no shells occurred, gave no *M. pomum*. Their outward dispersion from a reef seems to depend on the slope of the bottom and the extent of shell debris from the reef. In areas where the slope from the reef was sharp, the apple murexes were normally found in close proximity to the reef. One of their main sources of food seemed to be oysters that were broken from the reef and washed down into the area which they in-

TABLE 4

MORTALITY OF CAGED OYSTERS CAUSED BY *Murex pomum*,
PLACED IN CAGES 29 MAY 1955

Cage 1				Cage 2			
Date		No. Pres.	No. Dead	% Dead	No. Pres.	No. Dead	% Dead
June	4	10	0	0.0	10	0	0.0
	11	10	1	10.0	10	1	10.0
	16	10	1	10.0	10	0	0.0
	25	10	1	10.0	10	1	10.0
July	5	10	0	0.0	10	0	0.0
	9	10	0	0.0	10	1	10.0
	16	10	0	0.0	10	0	0.0
	23	10	0	0.0	10	0	0.0
	30	10	0	0.0	10	0	0.0
Aug.	6	10	0	0.0	10	0	0.0
	12	10	0	0.0	10	0	0.0
	20	10	0	0.0	10	0	0.0
	28	10	1	10.0	10	2	20.0
Sept.	4	10	0	0.0	10	1	10.0
	10	10	0	0.0	10	0	0.0
	17	10	2	20.0	10	2	20.0
	23	10	0	0.0	10	0	0.0
Oct.	1	10	0	0.0	10	0	0.0
	8	10	0	0.0	10	0	0.0
	15	10	0	0.0	10	0	0.0
	22	10	0	0.0	10	0	0.0
Totals			6		8		

habit. Another source of food was the small oysters, both *C. virginica* and especially *Ostrea equestris* Say, which attached to the shell debris. The senior author has examined many of this latter species in the harbor and a large majority of them, especially those over about 10 mm in length, were killed by *Murex*.

Population counts were undertaken only below such reefs where *M. pomum* were found. Through transects on randomly selected areas it was found that there were approximately 2 *M. pomum* per square meter in the areas examined. *M. pomum* were counted only around the perimeter of Sting-A-Ree Island and the reefs of Mutsure Jima.

The only method used by *Murex pomum* to open oysters was to drill through the valves. Figure 4 shows oysters that were drilled by caged *M. pomum*. Usually they drill near the middle part of one of the valves, but other than this no consistency was noted. The diameter of the hole is approximately 2 mm. The minimum time required to

drill an oyster could not be established, but it was less than 7 days, since the oyster was drilled and eaten between examination dates. Orton (1927), working with *Ocenebra* (*Murex*) *erinacea* Lam. found it required 5 to 7 days to drill an oyster 2.5 to 5 cm long. During the entire time that the murexes were caged (21 weeks), one of them drilled oysters at an average rate of 0.4 oysters per week and the other drilled at the rate of 0.3 oysters per week (Table 4). No oysters were killed by the snails during the period from 9 July to 20 August.

Because of the conditions in the lagoon in Sting-A-Ree Island, *Murex pomum* were not present. From observations near the reefs where apple murexes are found abundantly, it was observed that their predation on oysters was severe, but only on those oysters that became detached from the intertidal reefs or on the small spat, (especially *Ostrea equestris*) that attached subtidally. No snails were ever found on the intertidal reefs and no drilled oysters were found that would indicate that a vertical migration onto the reef might occur.

Thais haemastoma, southern oyster drill

Thais haemastoma is very rare in Alligator Harbor. A preliminary cage experiment was conducted from the last of May through September, but the results are too meagre to discuss. Only one oyster



FIGURE 5. Oyster killed by the Gulf oyster drill, *Thais haemastoma*. A slight notch can be seen in the right valve (valve with inner surface showing) near the posterior end (bill).

(Figure 5) was definitely known to be killed by *T. haemastoma* during the cage experiment, although a total of 6 were found dead during the period of observations. Where the drill occurs in abundance, it is one of the most serious oyster enemies in the Gulf region (Gunter, 1953, Butler, 1954). However, it could not be considered a serious enemy in Alligator Harbor because of its scarcity.

Pleuroploca gigantea, Florida horse conch

Pleuroploca gigantea did not kill any oysters. One of the two *P. gigantea* died after 8 weeks and the experiment was terminated. The conch is a conspicuous element of the fauna of Alligator Harbor, partly because of its large size, but from these preliminary observations is not to be considered an enemy of oysters.

Xanthid crabs

Menippe mercenaria, the stone crab, and *Panopeus herbstii* H Milne Edwards, the mud crab, are the only xanthid crabs found in the harbor that are of large enough size to be capable of killing significant numbers of adult oysters. Other mud crabs occur and undoubtedly kill oysters of spat size. The xanthid crabs are commonly found on the oyster reefs in the harbor (Wass, 1955).

TABLE 5
MORTALITY OF CAGED OYSTERS CAUSED BY *Menippe mercenaria*,
PLACED IN CAGE 30 JULY 1955

Date	Oysters Present	Number Dead	Per Cent Dead
Aug. 6	20	10	50.0
12	25	23	92.0
20	100	60	60.0
28	100	38	38.0
Sept. 4	100	51	51.0
10	100	19	19.0
17	100	16	16.0
Oct. 1	100	20	20.0
Total		237	

One stone crab, 80 mm in width, was caged for nine weeks with oysters. During this period the crab killed 237 oysters, or an average of 26 oysters per week. The maximum number killed in one week was 60 (Table 5). These oysters ranged in length from 50 to 60 mm. The crabs killed these oysters by cracking the shells. Figure 6 shows some of the oysters that were killed by the caged crabs. Although only large

pieces of the valves are shown in the photograph, many of the valves were finely fragmented.

Stone crabs had the habit of carrying off dead and live oysters. The valves of dead oysters, along with live oysters, were commonly found bordering stone crab burrows. The empty shells may have been carried off for the commensal organisms that inhabit the oyster's valves (Gunter, 1955).

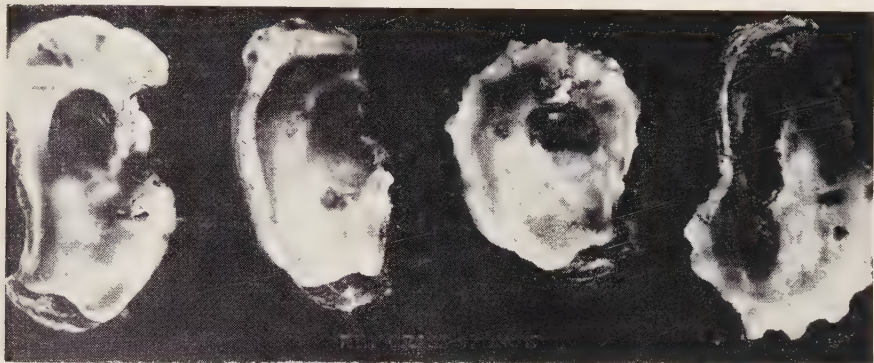


FIGURE 6. Oysters killed by the stone crab, *Menippe mercenaria*. The crab crushes the oyster shell with its powerful chelae. Often the shells are broken into small fragments.

Menzel and Hopkins (1955), in a more extensive study, gave an average mortality rate of oysters caused by *M. mercenaria* as 0.6 per day. This study covered various sizes of oysters and crabs during an entire year and during the colder months the predation was very low or ceased entirely. Also of importance are the other species of xanthid crabs which are numerous on the oyster reefs. Landers (1954) found that *Neopanope texana* Stimpson is a serious predator of *Mercenaria mercenaria* (L.) that are less than 10 mm in length.

Callinectes sapidus, blue crab

Blue crabs are very numerous in the area. They were usually seen in abundance on the oyster reefs. The crabs were especially numerous with the incoming tide and have been observed in very shallow water. Much of their feeding activity seemed to be scavenging.

Two blue crabs were kept in separate cages with oysters until the death of the crabs. Even though only oysters were placed in the cages it was noticed that various small animals were continuously present, gaining entrance though the $\frac{1}{2}$ inch mesh screen from which the cages were constructed. It is possible that these organisms, such as shrimp

TABLE 6

MORTALITY OF CAGED OYSTERS CAUSED BY *Callinectes sapidus*
 A CONSTANT NUMBER OF 25 OYSTERS WERE MAINTAINED AND
 PLACED IN CAGES 30 APRIL 1955

Date	Cage 1		Cage 2	
	No. Dead	% Dead	No. Dead	% Dead
May	10	0	0	0.0
	17	0	0	0.0
	22	crab died, replaced	crab died, replaced	
	29	0	0	0.0
June	4	0	0	0.0
	11	0	0	0.0
	18	crab died, replaced	crab died, replaced	
	25	0	0	0.0
July	5	0	0	0.0
	9	0	0	0.0
	16	0	0	0.0
	23	crab died, replaced	crab died, discontinued	
	30*	2		8.0
Aug.	6	3		12.0
	12	1		4.0
	20	8		32.0
	28	1		4.0
Sept.	4	0		0.0
	10	0		0.0
	17	crab died, discontinued		

*Smaller size oysters placed in cage.

and small blennioid fishes, may have been eaten by the crabs, which may account for the diverse lengths of time each crab remained in the cage before dying (Table 6). When one of the crabs died in the cage it was replaced with another living crab. A total of 6 blue crabs died during the course of the observations without killing any oysters. The average size of the oysters placed in the cages with the crabs was between 50 and 60 mm in length. On 23 July the average size of the oysters was reduced to 40 mm. A crab was placed with these and killed 15 oysters the first 5 weeks. It died the eighth week. Examination of the oysters that were killed showed that the crab had opened the majority of them by breaking through weak spots in the valve at the point of normal attachment to the cluster (Figure 7).

Lunz (1947) considers the blue crab to be one of the most important oyster predators in South Carolina waters, and considers young oysters an easy prey for blue crabs. Carriker (1951) mentioned a

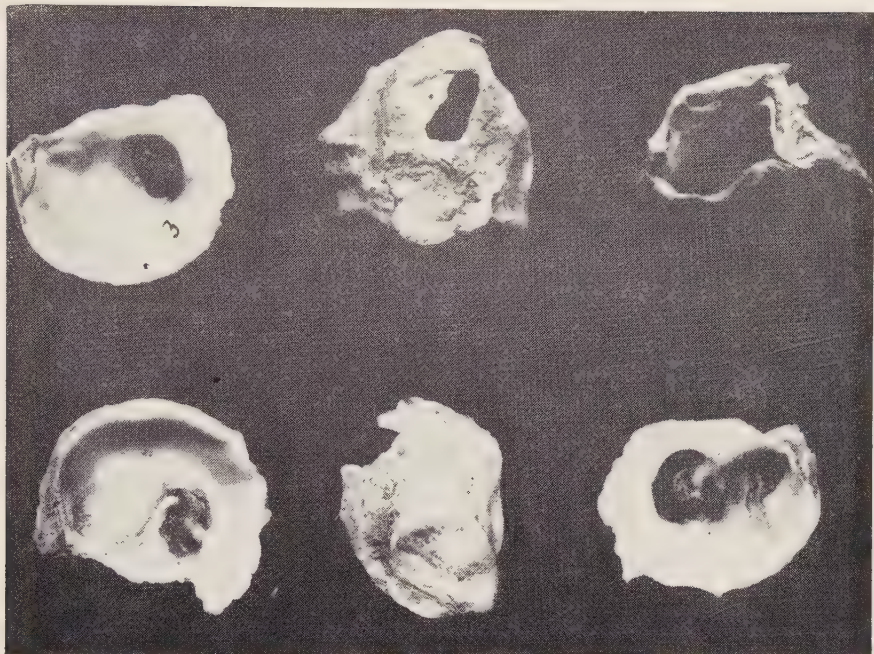


FIGURE 7. Oysters killed by the blue crab, *Callinectes sapidus*. These are smaller oysters than those in preceding figures. Often the shell is broken at the former place of attachment of the oyster to the substrate. In the smaller oysters the blue crab can break the shells with its chelae.

blue crab that opened six clams (*Mercenaria mercenaria*), measuring 3-4 cm, in seven days. Menzel and Hopkins (1955) found that mortality of large oysters in cages which contained blue crabs was not significantly higher than in cages containing only oysters. They stated that blue crabs are capable of killing weak oysters that would die in any case, and the importance of blue crabs lies in their predation of spat. They observed one blue crab which killed spat at the rate of 19 per day.

The results of the present study confirm the findings of Menzel and Hopkins in reference to large oysters. Of the eight blue crabs that were used in the observations, only one opened oysters, and these were small. It was noticed that some of the crabs made no attempt to open oysters, which indicates that oysters may not be part of their diet. They have been observed, however, especially on the reef during the summer months when mortality was unusually high, moving from one oyster to another, pinching the oyster's valves until one was found

to be weak or gaping. The oyster was then pried and pinched until it opened.

SUMMARY

1. Observations were made in Alligator Harbor on the distribution and ability to kill oysters of the following known or suspected predators: *Busycon contrarium* Conrad, *Melongena corona* Gmelin, *Murex pomum* Gmelin, *Thais haemastoma* Conrad, *Pleuroploca gigantea* Keiner, *Menippe mercenaria* Say and *Callinectes sapidus* Rathbun.
2. Lightning whelks, *Busycon contrarium*, were numerous around oyster reefs and were very destructive. They killed oysters either by chipping the edges of the shells to gain entrance, or by separating the valves by force.
3. Crown conchs, *Melongena corona*, were not established definitely as oyster enemies of any consequence although they were observed feeding on mollusks. It was observed that the conch quickly inserted the proboscis while the mollusk was relaxed and open. This manner of entry leaves no mark on the dead oyster shell. Therefore it is hard to assess the damage done to the oysters by this snail. Crown conchs were restricted in their abundance and over all the population was low.
4. Apple murexes, *Murex pomum*, drill holes in the oysters, and are very destructive to oysters below low water. They were not found intertidally on oyster reefs but were fairly numerous in an area below certain oyster reefs.
5. Southern oyster drills, *Thais haemastoma*, are very scarce in the area under study.
6. Florida horse conchs, *Pleuroploca gigantea*, sporadic in occurrence, were never seen feeding on oysters and did not do so when placed in cages with oysters.
7. Stone crabs, *Menippe mercenaria*, were very destructive to oysters. They along with the other xanthid crabs are very numerous on the reefs.
8. Blue crabs, *Callinectes sapidus*, were found to be enemies of small or "weak" oysters, but not large healthy oysters. Blue crabs are often very numerous in the oyster reefs, especially during the incoming tide.

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A DEEP SEA CERATIOID ANGLER-FISH OF THE GENUS *GIGANTACTIS* FROM FLORIDA¹

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ABSTRACT

The largest specimen known (standard length, 314 mm) of the ceratioid genus *Gigantactis* was collected off New Smyrna Beach, Florida, in 210 fathoms. A detailed description is presented from measurements and examination of the intact specimen. Since the specimen is no longer available no name is proposed for the species.

A brief discussion of the gigantactinids is given with reference to the present record and the principal literature reviews of the group.

INTRODUCTION AND ACKNOWLEDGMENTS

Despite three comprehensive reviews of the ceratioid anglers (Regan, 1926; Regan and Trewavas, 1932; Bertelsen, 1951) much remains to be learned about the group. This is especially true of the gigantactinids. Bertelsen (1951: 147-148) stated, "The separation of the *Gigantactis* species, which is based on differences in the appearance of the esca as well as in the relative length of the illicium and caudal peduncle, may be regarded as uncertain. . . 9 of the 11 known, metamorphosed females have been set up as types for various species and the remaining 2 have been referred to the past described species without detailed investigation or description." The capture of a large specimen of *Gigantactis* off the Florida coast is therefore noteworthy.

Mr. Al Pflueger, Miami taxidermist, made the specimen available and aided in many ways. We are indebted to Mrs. Marion Grey of the Chicago Natural History Museum for information. This study has been supported in part by a grant-in-aid from the National Science Foundation (NSF-G-3881) which the authors gratefully acknowledge.

Gigantactis sp.

The specimen, a female, 314.0 mm in standard length was collected by Mr. Williams, a commercial fisherman, in 210 fathoms east of New Smyrna Beach, on the northeastern coast of Florida. The trawling operation, at night, also yielded a considerable number of *Chaunax pictus*. It is regrettable that this most unusual specimen had to be mounted and returned to Mr. Williams and therefore is not available for museum deposition.

¹Contribution No. 201 from The Marine Laboratory, University of Miami.

The following description and the photographs were made from the intact specimen. All measurements are in millimeters while the numbers in parentheses indicate thousandths of standard length.

Predorsal distance (to concealed base of first ray), 174.7 (556). Preanal distance (to concealed base of first ray), 181.2 (577). Tip of snout to insertion (upper edge) of pectoral fin, 76.8 (245). Depth of body at dorsal-fin origin, 79.0 (252), at pectoral-fin, 64.6 (206). Greatest width of head (bony), 31.8 (101). Length of illicium (incomplete), 300.0 (956). Lateral width of illicium at base, 3.0 (10). Longitudinal width of illicium at base, 5.8 (18). Length of pectoral-fin peduncle, 12.0 (38). Longest pectoral ray, 20.9 (67). Posterior edge of hypural plate (midpoint) to insertion of last dorsal ray, 72.0 (229), to insertion of last anal ray, 69.8 (222). Least depth of caudal peduncle, 30.2 (96). Longest caudal ray, 77.7 (247). Eye diameter (horizontal), 2.6 (8). Diameter of gill opening, 11.5 (37).

The fish is uniformly black throughout, (Figs. 1, 2) except where the skin has been torn or scraped away. The oral cavity is also black. The skin has a texture like fine sandpaper.

The illicium is broken and its true length is unknown. All other species (metamorphosed females) of *Gigantactis* possess a bulbous "bait" or esca at the tip of the illicium and it is presumed that the present specimen did also. The esca is in part a light organ of which a general account is given by Marshall (1954: 251, 268-270, fig. XI, 2).

The basal portions of the dorsal- and anal-fin rays are enveloped in a heavy fold of skin so that their origins appear farther caudad than is the case (Fig. 1). Reference to the morphological data listed above will serve to properly locate the fin insertions. The distal portions of the dorsal and anal rays project from this fleshy base and are not connected by a membrane. A greater portion of the anterior rays is enclosed by the fleshy base than of the posterior rays. The caudal fin is somewhat similar in this respect; the middle rays are free for three-quarters of their length while the upper and lower rays are free for one-third of their length. If the tips of the free caudal rays are considered, the caudal margin is truncate. Fin-ray counts are as follows: dorsal—7, anal—7, caudal—9, pectoral—17 in each. The pectoral rays are connected by a fleshy membrane for one-third of their length and the distal edge of the fin is truncate. The pectoral fin is situated on a peduncle which is nearly half as long as the fin itself.

The teeth in the lower jaw are mainly in four rows. Six teeth, the



FIGURE 1. Lateral view of a female *Gigantactis* sp. (standard length, 314 mm) taken in 210 fathoms east of New Smyrna Beach, Florida, February, 1957. A short exposure was used in the print to show detail. The specimen was black.



FIGURE 2. Lateral view of head of same specimen of *Gigantactis* sp. as in Figure 1. The dangling tooth at the anterior edge of the lower jaw is broken and not in natural position.

longest about 7.5 mm in length, are in the first row which is on the outside of the jaw (Fig. 2). The second row is also on the outside of the jaw. Its posterior teeth are longer than the anterior ones (longest about 5 mm). All teeth are slender and fang-like, their tips directed toward the inside of the mouth. The inner two rows on the lower jaw are on the upper surface of the dentary. The innermost row contains the larger teeth; all are curved toward the interior of the oral cavity. There are about 40 and 26 teeth on the third and fourth rows respectively and the anterior ones in each are much the larger. No teeth are present on the tongue.

The maxillary and premaxillary bear numerous small teeth in two irregular rows. The longest on the premaxillary is about 3 mm while the smallest at the posterior end of the maxillary is less than 0.5 mm. All teeth on the upper jaw are curved toward the mouth.

The palatine and pterygoid teeth form two semicircular dentigerous rows across the roof of the mouth. Five very large (10 mm) teeth are present on each palatine bone. The pterygoid teeth, equal in size to the palatine teeth, exhibit bilateral asymmetry; 7 are present on one side and 10 on the other.

The gill opening is circular, its central portion obstructed by an island of skin similar in color and texture to that on the rest of the body. The actual opening is thus confined to the periphery of the circle.

Two parasitic copepods were attached to the left side, one at the base of the pectoral peduncle, the other above the anal fin. Tentatively they are identified with the family Lernaeidae by Alan Lewis of The Marine Laboratory.

DISCUSSION

Bertelsen (1951: Table 31) lists 10 species of *Gigantactis*, each, with one exception, based on a single metamorphosed female. Although a few males and many larvae are known, they have not been identified with any one species. It is therefore impossible to determine the amount of variation in such characters as the fin-ray counts. None of the known forms have both 7 dorsal and 7 anal rays. Nine caudal rays are a constant feature of all ten species, and Bertelsen (1951: 145) lists it as a family character. It is therefore puzzling to find only eight caudal rays in many of the illustrations (Regan and Trewavas, 1932, pl. 5 for example). None of the descriptions corresponds to the

Florida specimen in these characters nor in dentition and details of body form. An undescribed species is surely represented.

Several factors prevent us from proposing a specific name at this time. 1) The specimen no longer exists and there is little likelihood that the mount will be donated to any museum. 2) The illicium is incomplete and the esca therefore missing, both of which furnish important specific characters. 3) Since few specimens exist for any species one can not assess the amount of morphological change that may occur with growth. Our "specimen" (standard length, 314 mm) is much larger than any metamorphosed female of the other species (largest, of *macronema*, is only 100 mm in standard length) and comparison is therefore difficult.

Grey (1956: 266-269) summarizes the depth distributions of the various species of *Gigantactis*. Most occur below 1700 meters although *G. perlatus* Beebe and Crane (914 meters) and *G. filibulbosus* Fraser-Brunner (320 meters) are from much shallower sites. The Florida specimen was trawled in 210 fathoms (approximately 384 meters); this station is thus one of the shallower known for the group.

Since adults of *Gigantactis* are scarce and the largest specimen was taken by a commercial trawl, it is suggested that the gigantactinids are rather active swimmers, able to avoid the more usual scientific deep-water gear. Regan (1926: 11) made a similar suggestion on morphological grounds.

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PREDATION OF PELECYPODS AND GASTROPODS BY *FASCIOLARIA HUNTERIA* (PERRY)

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ABSTRACT

Laboratory and field predation of pelecypods and gastropods by *Fasciolaria hunteria* are described. *Fasciolaria* opens pelecypods by wedging its shell between the valves. Small gastropods are enveloped by the foot, while larger gastropods are eaten while the predator's foot holds out the operculum. A variety of pelecypods are eaten, oysters being the most attractive. Five gastropod species were eaten, including the oyster drill. Oyster drills are more attractive to *Fasciolaria* than are oysters, rates of daily predation of drills, in the presence of oysters, being as high as 5.7 drills/*Fasciolaria*. *Fasciolaria* are found concentrated on oyster areas where drills or oysters probably form a major part of their diet.

INTRODUCTION

Ganaros (1957), reporting a fungus which invades the egg capsules of *Urosalpinx cinerea*, points out the remarkable scarcity of enemies of this troublesome oyster pest. Reviewing oyster drill literature, Carriker (1955) makes no mention of any enemy that might serve as a biological check to this species. Although Flower (1954) noted that *Polinices duplicatus* would eat drills when confined in an aquarium, its affinity for sandy bottoms effectively limits the chances for natural predation of *Urosalpinx*. In many areas, *Urosalpinx* is recognized as the most important oyster enemy (Carriker, 1955).

In the light of these facts, it seems desirable to report the feeding habits of *Fasciolaria hunteria* (Perry) ($\equiv F. distans$), a natural predator of drills. The methods and extent of laboratory predation of both pelecypods and gastropods are described, with a cage experiment and some field notes.

While studying *Busycon*, Magalhaes (1948) observed *Fasciolaria* feeding on smaller snails. However, no investigations of the feeding habits of this species have appeared in the literature.

LABORATORY STUDIES

Methods.

A series of experiments was conducted from June to August, 1957, in aquaria and water table compartments at the Institute of Fisheries

Research. Circulating sea water was supplied from Bogue Sound where salinity ranged from 34.5 to 36.5 parts per thousand. Water temperature ranged from 24 to 31°C. Occasionally, several gallon jars and 20-gallon aquaria were arranged in series with siphons so that several feeding experiments could be run simultaneously. Such an arrangement permitted the insertion of control animals in a separate container where they were exposed to the water flowing from experimental containers.

Fasciolaria hunteria were collected in the vicinity of Beaufort Inlet. They ranged in length from 4.7 to 10.3 cm with most between 7.5 and 9.0 cm. The pelecypod and gastropod prey were also obtained near Beaufort Inlet from intertidal areas.

Method of opening pelecypods.

When attacking an oyster in the laboratory, *Fasciolaria* usually assumes a position on the upper valve, with the outer lip closely appressed to the margin of the oyster's valves (Fig. 1a). Encrusting organisms and scales of shell are usually scraped from a small area of the upper valve by action of the radula and outer lip of the shell, enabling the foot to supply a powerful suction for its attachment to this smoothed area. (Of 100 oysters opened by *Fasciolaria* in the laboratory, 78 bore such a smoothed area.) Here, it awaits an opening of the oyster's valves, at which time the *Fasciolaria* rotates its shell, pressing the outer lip between the valves. The inpressing lip and the responding oyster's attempt to shut its valves usually result in chipping the thin margins of the oyster's shell. Once the valves are held apart, the *Fasciolaria* extends its proboscis and devours the oyster meats. *Fasciolaria* does not eat associated oyster crabs, *Pinnothereus ostreum*, but leaves them intact between the clean oyster valves.

Of 100 oysters opened by *Fasciolaria*, 91 showed signs of marginal chipping (Fig. 1b). Most of these were chipped on the dorso-posterior margin, the part closest to the exhalent currents. The predominance of attack at this point indicates that *Fasciolaria* is attracted by substances in the exhalent currents of water.

Whenever a sizable pelecypod or gastropod (5 cm or more) was eaten, other *Fasciolaria* gathered and rasped the soft parts, apparently attracted by materials released by the prey. Forty-two of 100 oysters eaten by *Fasciolaria* showed two or more chipped places. Unsuccessful attacks probably caused some of these, but many were the result of an oyster being penetrated simultaneously by several *Fasciolaria*.

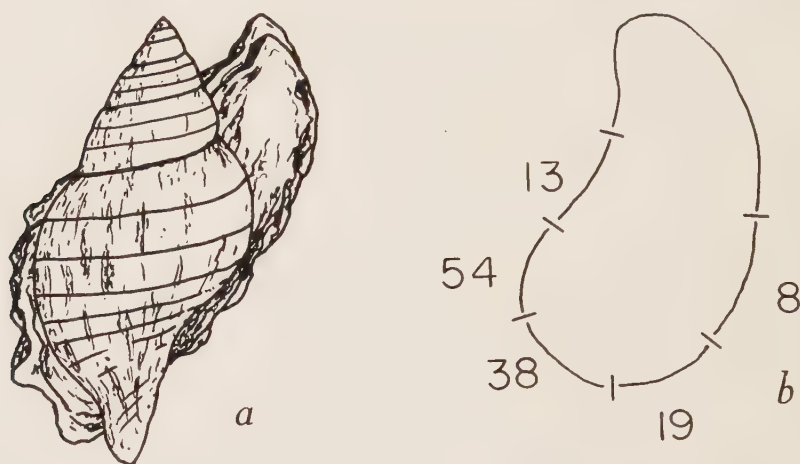


FIGURE 1. a. *Fasciolaria hunteria* in position on the upper valve of *Crassostrea virginica* prepared to wedge its outer lip between the oyster's valves. b. Distribution of chipped margins on the valves of 100 oysters opened by *Fasciolaria hunteria*.

The method of opening *Mercenaria* (= *Venus* of authors), *Modiolus*, and *Aequipecten* was a modification of this method and very similar in the three forms. Although each of these was examined microscopically, no signs of radular scraping were detected on the valves. Essentially, entry of *Fasciolaria* in these forms is effected by insertion of the outer lip of the shell between the valves, and is aided by incidental chipping of the margins when the pelecypod attempts to close. Such chipping was apparent in *Mercenaria*, scarcely detectable in *Modiolus*, and absent in *Aequipecten*. Occasionally, the outer lip of the *Fasciolaria* shell shows some signs of chipping, usually an unevenness, where the lip was caught between closing pelecypod valves. This irregularity is not as pronounced as that found in *Busycon* which actively uses the outer lip in chipping pelecypod valves (Carriker, 1951).

Basically the method of opening pelecypods is similar to that described by Carriker for *Busycon*, except for the absence of active chipping by the predator. The clearing of an area by radular scraping on the upper valve of oysters has no counterpart in *Busycon* behavior; instead it resembles the behavior of older *Thais* individuals which actively drill marginal holes in oysters (Butler, 1953).

Method of capturing gastropods.

Although Morris (1951) notes that the Fascioliariidae are slow and

deliberate in their movements, individual *Fasciolaria* specimens glide similar in the three forms. Although each of these was examined micro-movement, they can readily overtake most small gastropods. The foot arches over the shell of the prey and envelopes it almost completely. If disturbed at this stage, the *Fasciolaria* will draw its foot into the shell, still enveloping the prey. While held in such a manner, soft parts of the prey are removed from the shell by radular action. Occasionally the columellar muscle in *Cantharus tinctus* is left intact although the epithelial layers and other soft parts are eaten.

When another *Fasciolaria* is attacked, a different method is utilized. In this case, the size of predator and prey are more nearly alike. The attacking animal attaches firmly to the operculum of its victim, preventing the characteristic withdrawal of soft parts to the relative safety of the shell. While holding the prey in this expanded condition, the predator rasps and devours the soft parts except the columellar muscle attached to the operculum. The author has observed *Pleuroploca gigantea* using a similar method to attack gastropods.

RESULTS

Pelecypods (Table 1).

Because *Fasciolaria* was observed eating oysters at low tide under natural conditions, the first experiment concerned predation of oysters. During a 21-day period, 15 oysters and three of the smaller *Fasciolaria* were eaten. (Eight clusters of egg capsules were laid on the oysters.)

Mixed pelecypods were offered to *Fasciolaria* in a second experiment in which equal proportions of clams, mussels, and oysters were maintained for a 30-day period. Uneaten animals were replaced several times to insure that their condition did not affect the results. The *Fasciolaria* ate all scallops presented and many oysters; however, again, a smaller specimen was cannibalized.

In a third experiment, 13 *Fasciolaria* ate only one *Ostrea equestris* in 22 days while three snails were eaten by their own species. During this experiment, one *Crassostrea* was dropped into the aquarium and was consumed within 24 hours. This apparent preference for *Crassostrea* over *Ostrea* was tested for seven days in a fourth experiment involving equal numbers of both species of oysters and ten *Fasciolaria*. Only four *Crassostrea* were eaten.

TABLE 1
LABORATORY PREDATION OF PELECYPODS BY *Fasciolaria hunteria*.

	Prey	Length	Number Consumed	Rate ¹	Number of <i>Fasciolaria</i>
1	<i>Crassostrea virginica</i>	2.7-8.8 cm	15		
	(<i>Fasciolaria hunteria</i>)	5.5-7.5 cm	3		
	Total		18	0.061	14
2	<i>Crassostrea virginica</i>	2.3-11.6 cm	46		
	<i>Aequipecten irradians</i>	4.4-6.0 cm	9		
	<i>Modiolus demissus</i>	6.7 cm	1		
	<i>Mercenaria mercenaria</i>	-	0		
	(<i>Fasciolaria hunteria</i>)	4.9 cm	1		
	Total		57	0.087	20-30
Additional pelecypods eaten-					
	<i>Mytilus edulis</i>	1.1-2.3 cm	34		
	<i>Aequipecten irradians</i>	4.1-5.7 cm	10		
	<i>Mercenaria mercenaria</i>	5.7-6.3 cm	5		
	<i>Brachidontes exustus</i>	1.5-1.7 cm	3		
	<i>Modiolus demissus</i>	7.4-9.6 cm	2		
	<i>Anomia simplex</i>	2.9-3.1 cm	2		
	<i>Chione cancellata</i>	3.8 cm	1		
	<i>Ostrea equestris</i>	2.7 cm	1		

¹"Rate" indicates the number of mollusks consumed per *Fasciolaria* per day.

Additional pelecypods eaten by *Fasciolaria* in the Laboratory are listed in Table 1.

Gastropods (Table 2).

A series of ten experiments were conducted placing *Fasciolaria* with a single species of gastropod. These were set up in wide-mouth gallon jars capped by a small glass dish leaving only a small marginal space for inlet and drain siphons. Occasionally small gastropods escaped through this opening. In the first of the gastropod experiments, for example, three oyster drills escaped. These experiments exposed *Urosalpinx cinerea*, *Nassarius obsoletus*, *Nassarius vibex*, *Cantharus tinctus*, and *Thais haemastoma floridana* to possible predation by *Fasciolaria*. Only *Thais* was not eaten. Both *Urosalpinx cinerea* and *Nassarius obsoletus* were eaten at high rates.

Comparisons between species (Table 3).

Although *Nassarius vibex* was preyed upon less than *Nassarius obsoletus* or *Urosalpinx cinerea*, it was not clear which of the latter

TABLE 2

GASTROPODS PRESENTED TO *Fasciolaria hunteria* IN LABORATORY EXPERIMENTS,
THEIR FATE, AND RATE OF PREDATION.

Prey	Length (cm)	Number Eaten	<i>Fasciolaria</i> Length (cm)	Days	Rate ¹
25 <i>Urosalpinx cinerea</i>	1.6-2.1	22	7.5,8.1	7	1.57
50 <i>Urosalpinx cinerea</i>	1.4-2.3	34	8.6,9.6	7	2.43
60 <i>Urosalpinx cinerea</i>	0.9-2.8	54	7.5,8.0,8.5	8	2.25
60 <i>Urosalpinx cinerea</i>	1.2-2.5	39	8.5,9.4	8	2.44
60 <i>Nassarius obsoletus</i>	-	38	7.5,8.0	8	2.40
60 <i>Nassarius vibex</i>	-	22	7.7,7.9	7	1.57
2 <i>Thais haemastoma</i>	(5.2,5.7)	0	9.9,10.2	7	0
2 <i>Thais haemastoma</i>	(5.5,5.7)	0	9.9,10.2	7	0
42 <i>Cantharus tinctus</i>	1.3-2.8	19	8.7,9.1	7	1.36
50 <i>Cantharus tinctus</i>	2.0-2.9	15	8.7,9.1	7	1.07

¹"Rate" indicates the number of gastropods consumed per *Fasciolaria* per day.

species was more attractive to *Fasciolaria*. Therefore, in each of four comparison experiments, two of these species were presented to two *Fasciolaria* for a period of seven days. Each experiment was run with 25 animals of each species.

TABLE 3

COMPARISON OF *Fasciolaria* PREDATION UPON GASTROPODS.

Prey	Length	Number Consumed	Rate ¹
1 <i>Nassarius obsoletus</i>	1.5-1.9 cm	25	
<i>Nassarius obsoletus</i>	1.5-1.9 cm	23	
Total		48	3.43
*2 <i>Nassarius obsoletus</i>	1.1-2.1 cm	13	
<i>Nassarius obsoletus</i>	1.1-2.1 cm	35	
Total		48	3.43
3 <i>Nassarius vibex</i>	1.3-1.5 cm	19	
<i>Nassarius vibex</i>	1.3-1.5 cm	5	
Total		24	1.71
*4 <i>Nassarius vibex</i>	1.1-1.6 cm	26	
<i>Nassarius vibex</i>	1.1-1.6 cm	7	
Total		33	2.36

¹"Rate" indicates the number of gastropods consumed per *Fasciolaria* per day.
In starred experiments, dead animals were replaced daily.

The first and second experiments involved *Urosalpinx cinerea* and *Nassarius obsoletus*. In the first, all but two specimens were eaten; therefore, in the second, dead snails were replaced daily to prevent the availability of prey from affecting any apparent preference shown by *Fasciolaria*. When thus maintained in equal numbers, *Nassarius obsoletus* fell prey to *Fasciolaria* much more often than *Urosalpinx* did.

In a similar manner, the third and fourth experiments both involved *Urosalpinx cinerea* and *Nassarius vibex*. In the fourth experiment dead snails were replaced as in the second experiment. This treatment did not affect the ratio of predation of the two species. Periodic examination of the animals probably stimulated them to greater activity and may be responsible for the higher over-all predation rate. In both cases, many more *Urosalpinx* were eaten than *Nassarius vibex*.

On the basis of these experiments, a ranking of the comparative attractiveness of these three gastropods would be:

1. *Nassarius obsoletus*
2. *Urosalpinx cinerea*
3. *Nassarius vibex*.

Comparison between oysters and drills (Table 4).

In a preliminary experiment on the relative attractiveness of oysters and drills, six *Fasciolaria* were placed in an aquarium with *Crassostrea virginica* and 50 *Urosalpinx cinerea*. After seven days, only one 5.8-cm oyster had been opened, but 47 of the drills had been killed.

TABLE 4

DAILY MORTALITY OF OYSTERS AND DRILLS PLACED IN DIFFERENT RATIOS INTO COMPARTMENTS WITH GROUPS OF SEVEN *Fasciolaria hunteria*.

	Prey	Day-	1	2	3	4	5	6	7	8	Total
{	12 <i>Urosalpinx</i>		6	2	4	-	-	-	-	-	12
	25 <i>Crassostrea</i>		-	3	2	2	2	-	5	-	14
{	25 <i>Urosalpinx</i>		14	7	4	-	-	-	-	-	25
	25 <i>Crassostrea</i>		-	2	2	-	-	-	2	2	8
{	50 <i>Urosalpinx</i>		21	20	9	-	-	-	-	-	50
	25 <i>Crassostrea</i>		-	-	-	-	-	-	3	4	7
{	100 <i>Urosalpinx</i>		37	40	18	4	1	-	-	-	100
	25 <i>Crassostrea</i>		-	-	-	-	-	-	5	2	7

To determine the effects of different concentrations of drills upon the predatory activity of *Fasciolaria*, four groups of seven *Fasciolaria*

each were placed in adjacent compartments of a water table with different numbers of drills and 25 oysters. The proportion of drills to oysters in the four compartments was $\frac{1}{2}:1$, $1:1$, $2:1$, and $4:1$, respectively. Size composition of each *Fasciolaria* group was nearly identical. This series was run for an 8-day period during which daily examinations were made to determine the progress of predation in each compartment. As a control, a group of drills was confined in a perforated plastic cage which floated in one compartment. No deaths occurred among these control animals. The experimental results are presented in Table 4.

In the presence of a sufficient number of drills, the oysters were "protected" from attack by *Fasciolaria*. Where 50 or more drills were presented to the *Fasciolaria*, at a ratio of about 7 drills to 1 *Fasciolaria*, the latter did not attack the oysters until two or three days after the drills had been consumed. When fewer drills were presented, the *Fasciolaria* began eating oysters while living drills were still present. After a week, all four groups of *Fasciolaria* were eating oysters, the group with the lowest initial number of drills having eaten more oysters than the other experimental groups. All drills had been captured and eaten by the fifth day, daily rates of predation upon drills having been as high as 5.3 and 5.7 drills per *Fasciolaria*.

FIELD STUDIES

Methods.

A field check was made upon the predation of pelecypods observed in the laboratory. Two cages were constructed of 1-inch mesh galvanized chicken wire, 4 feet square and 1 foot high, and placed in a protected body of water located in a marsh on the south side of Bogue Sound. The edges of the cage were buried 6 to 8 inches in the bottom to prevent entry or escape of predators. At low tide the water remained about 4 inches deep. The bottom was black muddy sand. Water conditions at this location were similar to those in the laboratory tanks, with the possible exception of greater temperature extremes at low tide. Although no predatory snails were observed, a number of blue crabs (*Callinectes sapidus*) were present in the immediate area and in the surrounding marsh.

The animals used had been obtained from the same sources as the laboratory experimental animals. Mussels lived in the surrounding marsh, and several clams were raked from the cage areas. Into the experimental cage were placed 20 *Fasciolaria* (7.9-9.9 cm in length),

100 oysters (4.8-11.8 cm), 100 mussels (5.1-9.4 cm), 30 clams (4.8-7.5 cm), and 12 scallops (4.2-5.8 cm). Into a control cage, located adjacent to the experimental cage, were placed 100 oysters (5.7-12.0 cm), 39 mussels (4.4-5.7 cm), 30 clams (4.2-8.0 cm), and 12 scallops (4.4-5.7 cm). The animals were caged July 6 and left undisturbed till August 27, a period of 51 days.

Observations.

The fates of animals placed in cages are given in Table 5. One *Fasciolaria* shell had been occupied by a hermit crab, *Clibinarius*

TABLE 5

MOLLUSKS INCLUDED IN CAGES ON JULY 6 AND THEIR FATE ON AUGUST 27.

Animals	Initial Quantity	Fate of Animals
Experimental cage-		
<i>Fasciolaria</i>	20	19 recovered alive; 1 shell occupied by hermit crab.
<i>Crassostrea</i>	100	71 dead; apparently opened by <i>Fasciolaria</i> .
<i>Modiolus</i>	100	Of 41 dead, 13 had been opened by crabs, 28 by <i>Fasciolaria</i> .
<i>Mercenaria</i>	30	1 opened by <i>Fasciolaria</i> .
<i>Aequipecten</i>	12	11 dead, 1 recovered alive.
Control cage-		
<i>Crassostrea</i>	100	All but 4 recovered alive.
<i>Modiolus</i>	39	10 opened by crabs.
<i>Mercenaria</i>	30	All recovered alive.
<i>Aequipecten</i>	12	5 recovered alive; 7 dead.

vittatus. Deaths in the control cage serve as an estimate of deaths that can be attributed to causes other than *Fasciolaria* predation; in addition, broken mussel shells indicate some crab predation. When these corrections are applied, deaths of the following pelecypods can be attributed to *Fasciolaria* predation:

<i>Crassostrea virginica</i>	 67
<i>Modiolus demissus</i>	 28
<i>Aequipecten irradians</i>	 4
<i>Mercenaria mercenaria</i>	 1

Total 100

Pelecypods consumed per *Fasciolaria* per day 0.098

DISCUSSION

The rate of *Fasciolaria* predation of pelecypods in laboratory experiments agrees closely with the rate obtained in the field cage. Except for mussels, the proportions of pelecypods eaten under the two experimental arrangements are also similar. Notable is the greater number of mussels consumed in the cage.

Usually *Modiolus demissus* is only found in the upper part of the intertidal zone among roots and oyster shells. This distribution does not overlap the lower zones where *Fasciolaria* was collected in numbers, so that normally one would not expect mussels in the diet of *Fasciolaria*. However, the presence of *Fasciolaria* may be a factor which contributes to the exclusion of mussels from a particular zone by predation upon the juveniles. Compared with other pelecypods, there is a small quantity of soft parts in a mussel, and probably little storage of materials therein. Consequently, they may show a more rapid decline in "condition" under laboratory conditions of reduced feeding, and thus be less attractive to *Fasciolaria* than in nature.

Although scallops normally gape much of the time and would seem to be easy prey for a predator to wedge open, it is questionable whether they would form a major dietary item for *Fasciolaria*. Only a few scallops occur in the oyster beds where most of the *Fasciolaria* were collected, and they could probably escape from a *Fasciolaria* if they were not restricted by a cage or an aquarium.

The ability to remain tightly closed for long periods of time, as is well developed in *Mercenaria*, would serve as a protection from *Fasciolaria* for pelecypods. Because of its smaller size, *Fasciolaria* cannot dig clams out of sand as conchs (*Busycon* species) have been observed to do. This would serve as a further protection to *Mercenaria* under natural conditions.

The one *Fasciolaria* which died in the cage may have been killed by the hermit crab which occupied its shell, or by other *Fasciolaria*, as happened several times in laboratory experiments.

Oysters are the most attractive pelecypod prey for *Fasciolaria* under both field and laboratory conditions, and all but six of the specimens used in these experiments were collected in oyster areas. These six were dredged from a shell bottom in 6 to 12 feet of water. The most numerous collection of *Fasciolaria* was made during a two-day period when 51 were found among intertidal oysters that extended 75 yards along the shoreline. Sometimes *Fasciolaria* were found on sandy bot-

toms containing oysters and shell. They were not found on soft bottoms far from shell, as *Busycon* species, recognized soft-bottom forms, are often found. In view of the facts (1) that *Fasciolaria* attach their egg capsules to rock and shell, and (2) that the most fruitful collection of adults (noted above) coincided with a peak in reproductive activity, it would appear that *Fasciolaria* aggregate on hard bottoms primarily for reproductive purposes. However, feeding was observed on that occasion as well as copulation and egg-laying. Moreover, the author has collected adults from oyster clumps, oyster-covered rock jetties, and shell bottoms at all times of the year. In the Beaufort area then, *Fasciolaria hunteria* is a permanent member of the oyster bed community.

In a listing on the animals found on Texas coastal jetties, Whitten, Rosene, and Hedgpeth (1950) mentioned the collection of a single *Fasciolaria distans* (= *F. hunteria*) on a Port Aransas jetty, but regarded its occurrence there as an accident since it was a "soft-bottom species." However, *Fasciolaria* is not mentioned by Ladd (1951) in a study of molluscan community affinities on the Gulf coast, nor in the work of Emerson and Puffer (1953) on mollusks of Texas oyster beds.

The apparent preference shown by *Fasciolaria* for *Crassostrea virginica* over *Ostrea equestris* was not expected. Such differences in attractiveness may be partially responsible for differences in zonation observed for these two species, as well as differences in their spatfall reported by Menzel (1955).

Being absent in some years, and rarely attaining a size over 3 cm, *Mytilus edulis* approaches its southern limit at Beaufort. Because its local distribution does not overlap that of *Fasciolaria*, it probably is not a significant part of the diet of *Fasciolaria*. *Chione cancellata* was often found on top of the substrate with oysters and shell. It would be available to *Fasciolaria*, but apparently is not attractive. Because *Anomia simplex* compete with oyster spat for space and are not eaten by oyster drills (Carriker, 1955), it is notable that *Fasciolaria* ate intact *Anomia*.

These are the first reports of predation of pelecypods by *Fasciolaria hunteria*. Apparently a wide variety of pelecypods can serve as food, although the edible, eastern oyster seems to be the most attractive species.

These experiments clearly indicate the high rate at which *Fasciolaria* will devour small gastropods. Natural feeding of *Fasciolaria* upon

Urosalpinx, as well as *Nassarius* and *Terebra*, was observed by Magalhaes (1949) but has been generally overlooked.

There is a good correlation between size of the three gastropod species compared and their attractiveness to *Fasciolaria*. Generally, the specimens of *Nassarius obsoletus* were larger than those of *Urosalpinx*, although the over-all length of the drills may have been greater. The greater development of the siphon canal in drills gives them a proportionately greater length. *Nassarius vibex* is smaller than either of the other two species. On the other hand, both *Nassarius vibex* and *Nassarius obsoletus* are more active than *Urosalpinx*. Thus, the relative attractiveness of these species appears to be a function of their size, rather than of their relative activity.

Which of these species is more likely to form a major part of the diet of *Fasciolaria*? Although *Urosalpinx* is a recognized member of the oyster bed community, *Nassarius vibex* is typically a sand-flat species and *Nassarius obsoletus*, a mud-flat species. Their occurrence near oysters depends on the incursion of that particular bottom type upon the oyster bed and normally is much reduced. Therefore, on the basis of community relationships, *Urosalpinx* would appear to be the most important as natural prey for *Fasciolaria*.

Although Hackney (1944) observed and noted the interactions of a drill and a *Fasciolaria*, she misinterpreted their roles. She considered the drill which crawled upon the shell of a *Fasciolaria* a would-be predator; the leaping and jumping actions of the *Fasciolaria* were considered to be primarily defensive in nature, rather than an attempt to capture a particularly evasive victim. Magalhaes' observations indicated the actual relationship that exists between these two species, and the present experiments serve to verify it.

The repeated occurrence of cannibalism in the pelecypod experiments is an indication of the importance of gastropods in the diet of *Fasciolaria*, and the results of the comparisons between oysters and oyster drills bear this out. Although oysters are the most attractive pelecypod prey, *Fasciolaria* ate the gastropods first.

Applied to the oyster bed community, these results indicate that *Fasciolaria* would seek out and devour oyster drills in preference to oysters; it is a natural predator of the drill and probably important in control of natural drill populations. However, *Fasciolaria* will and does eat oysters occasionally in the field, though the conditions under which this occurs are not clearly understood. Presumably, the critical factor is the presence of a minimal number of small gastropods; however,

this minimal number has yet to be determined. Further study should also determine the effects of other factors upon this hypothetical minimum, and the frequency with which these conditions are met in nature.

Fasciolaria can be reared from egg capsules brought into the laboratory, for there is no pelagic phase in the life cycle. Like *Urosalpinx*, *Fasciolaria* possesses a "crawl-away larva," which is a miniature of the adult (McMurrich, 1886). During this study, six young *Fasciolaria* attained a size of about 1 cm in the laboratory; but success in rearing them is handicapped by their tendency to feed on one another, which they share with adult *Fasciolaria*.

Only between Cape Hatteras and Florida do the ranges of *Fasciolaria* and *Urosalpinx* overlap. In the U. S. National Museum, there are specimens of *Fasciolaria hunteria* from Beaufort, N. C., south to the Gulf of Mexico. *Fasciolaria* has not been found north of Cape Hatteras, in areas where the depredations of the oyster drill are serious.

The possibility exists that *Fasciolaria hunteria* might be a suitable organism for use in a "biological control" program for *Urosalpinx cinerea*, but much further study is required before its potentialities can be evaluated.

I wish to thank Dr. Melbourne R. Carriker of the University of North Carolina Department of Zoology for his advice and encouragement during this study.

SUMMARY

1. Studies on predatory habits of *Fasciolaria hunteria* were carried out in aquaria and water tables at the Institute of Fisheries Research and in cages in Bogue Sound, N. C.
2. *Fasciolaria* attacks pelecypods by wedging its shell between the valves. Entrance is often aided by coincidental chipping as the valves are closed.
3. When small gastropods are eaten, they are enveloped by the foot. In attacking larger gastropods, the operculum is held in the predator's foot while the soft parts are eaten.
4. *Fasciolaria* fed upon *Crassostrea virginica*, *Modiolus demissus*, *Mercenaria mercenaria*, *Aequipecten irradians*, *Mytilus edulis*, *Brachidontes exustus*, *Anomia simplex*, *Chione cancellata*, and *Ostrea equestris*. *Crassostrea*, *Aequipecten*, and *Modiolus*, in that order, were most attractive to *Fasciolaria*.
5. *Fasciolaria* fed upon *Urosalpinx cinerea*, *Nassarius vibex*, *Nassarius obsoletus*, *Cantharus tinctus*, and other *Fasciolaria hunteria*.

They did not feed on *Thais haemastoma floridana*. Of the first three, *Nassarius obsoletus* was the most attractive, and *Urosalpinx cinerea*, second.

6. Rates of predation by *Fasciolaria* expressed as the number of organisms consumed per *Fasciolaria* per day were as follows: mixed pelecypods, mostly *Crassostrea*, (in the laboratory) 0.087 and (in cages) 0.098; *Crassostrea*, 0.061 and 0.057; *Urosalpinx*, 2.25, 2.43, and 2.44; *Nassarius obsoletus*, 2.40; *Nassarius vibex*, 1.57; and *Cantharus tinctus*, 1.07 and 1.36.
7. *Urosalpinx* was more attractive to *Fasciolaria* than *Crassostrea*. When presented both oysters and drills in sufficient numbers, *Fasciolaria* attacked drills first and did not eat oysters until several days after all drills had been eaten. Rates of daily predation of *Urosalpinx* were as high as 5.3 and 5.7 drills per *Fasciolaria*.
8. *Fasciolaria* were found concentrated on oyster bottoms. There, small gastropods, particularly drills, or oysters make up a major part of their diet.

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EARLY DEVELOPMENT AND LARVAL DISTRIBUTION OF THE CARANGID FISH, *CARANX CRYSOS* (MITCHILL)¹

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ABSTRACT

The early development of the blue runner, *Caranx crysos* (Mitchill, 1815), is described and the early stages are illustrated. The distribution of the species is discussed based upon specimens in the collections of The Marine Laboratory and the United States National Museum. Food, spawning, growth, temperatures, salinities and depth of capture are discussed.

INTRODUCTION

The blue runner, *Caranx crysos* (Mitchill, 1815), is a widely distributed oceanic fish. It is known in the Western Atlantic from Halifax, Nova Scotia, to Recife, Brazil, and is widely distributed in the West Indian faunal region and along the western side of the Gulf Stream. It is extremely common along the lower east coast of Florida where it occurs singly and in schools, mainly concentrated between the Florida Current and the shore.

Although this species is not considered in the Florida region to be a food fish, it nevertheless is often eaten and according to the Florida Landings for 1956 over 613,711 pounds valued at \$26,880.00 were sold as food fish on both coasts of Florida. Although the meat is slightly dark and some people may consider it strong it is prized by jetty fishermen and those fishing from small boats. In general it is considered a trash fish by the deep sea sportfishermen. According to Wilcox (1902) it is one of the common food fishes appearing in the markets in Puerto Rico and Evermann and Marsh (1902) state that it is one of the best smaller gamefish in those waters and can be caught both still fishing and trolling. Vincent (1910) lists it as one of the better fishes in Trinidad where it is called "Carangue Grasse" and is often taken in seines. Metzelaar (1919) records it from both sides of the Atlantic and adds the common names "jager boca," "bau" and "deep water cavaly." Robins (1958) lists the preferred common names of Florida food and game fishes and here calls it the "Blue Runner."

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In addition to its use as a food fish, the blue runner is highly prized as a bait for other fish. It is particularly valued as a live bait for the larger reef fishes such as amberjacks, and for deep fishing for sailfish.

While as shown in this paper the main diet, at least of the smaller fish, is planktonic, blue runners are normally caught trolling with small Japanese feathers or a piece of white cloth tied to the shank of the hook, indicating a predilection for somewhat larger food, and they are often taken with shrimp in their stomachs.

During warm summers *Caranx crysos* appears far to the northward of its more common haunts, occurring in large numbers off Maryland, New Jersey, and as scattered individuals to the New England states. It seems probable that this northward summer distribution is facilitated by the course of the Gulf Stream and that the northern records are based upon summer stragglers.

Caranx crysos was first described by Mitchill in 1815 under the name *Scomber crysos* from off New York. The species has been mentioned and recorded by numerous workers since that date, probably the most recent being the monographic study by Ginsburg (1952) on the fishes of the family Carangidae of the northern Gulf of Mexico.

Few workers have recorded young *C. crysos* and none, to our knowledge, have described true larval stages. One of the earliest mentions of juveniles is given by Gunter (1935) who recorded young *Paratractus crysos* from the bell of the cannon ball jellyfish, *Stomolophus*. Nichols, in a series of papers (1938, 1939), has made the major contribution to our knowledge of the young of this species and of other species of *Caranx*. In his papers he recorded specimens as small as 12 mm standard length and gave proportions, counts, color notes and distributional data. His key to the young juveniles of these three species is helpful. Longley and Hildebrand (1941) reported young *C. crysos* below 100 mm from refuse in the tern rookery at the Dry Tortugas.

The present study is based upon a total of 148 specimens ranging in size from 2.7 to 163.0 mm in standard length mostly from plankton collections made by The Marine Laboratory in connection with the National Geographic Society-University of Miami Marine Laboratory Pelagic Fish Life History Program. The work was begun in 1953 by Voss and carried out by him through 1954 but due to other pressing matters its completion reflects the combined efforts of all three authors.

The authors wish to thank the National Geographic Society for their financial support of the program which made this study possible. They also wish to thank the authorities of the United States National Museum and in particular Dr. Leonard P. Schultz, Curator of Fishes, for making facilities available to one of us (Voss) in the division of fishes during the summer of 1954 and placing the specimens of *Caranx crysos*, *C. ruber* and *C. bartholomei* at his disposal for study. The authors also wish to thank Dr. C. Richard Robins, Curator of Fishes at The Marine Laboratory, for his many helpful suggestions and the critical reading of the manuscript and for the loan of material from the collections under his care.

MATERIALS AND METHODS

The majority of specimens examined in this study were taken by plankton nets or dip nets in the course of work carried out by The Marine Laboratory. All available station data are listed in Table 1. Specimens from stations listed as SL, NG, Supl., Y, and FR are, with the exception of a few of the Supls. and the Y specimens, from plankton tows. The letter designations denote plankton collections made for certain projects. UMMML and USNM refer to specimens in the collection of fishes at the University of Miami Marine Laboratory and the United States National Museum, respectively. Further information on the methods used in the plankton collecting and for the larval fish collection is given by N. Voss (1954). Hydrographic data for the Straits of Florida and the Caribbean Sea are given by Hela *et al* (1955). Data and conditions prevailing at the NG stations are given by Miller *et al* (1953), and for the SL stations by Bsharah (1957).

The terminology suggested by Hubbs (1943), LARVA, PRO-LARVA, POSTLARVA and JUVENILE, is used. Figures 2a-c, and 3a were drawn by Voss. Figure 3b was executed partly by Voss and partly by McKenney and Alexander. The remaining figures, tables and charts were made by McKenney and Alexander. The USNM specimens were identified and measured by Voss during the summer of 1954. All remaining specimens were examined by the authors collectively.

Measurements. Specimens up to 10 mm standard length were measured with a micrometer eyepiece and those larger than 10 mm with dividers. Measurements and counts were made on the left side of the specimens except when damaged, then the right side was used. Total

TABLE 1
Caranx crysos (MITCHILL, 1815). STATION DATA FOR SPECIMENS STUDIED.

Station	Date	Location	Depth M.	Time	Temp. °C	Sal. ‰	Illum.	Sfc. Temp.	No. of Spec.
SL 37, A-0	8/8/55	26°08'N 79°56'W	Sfc.	1238	27.1		10 ²	27.1	1
SL 40, B-1	5/10/55	"	46	0415-- 0445	28.8		10 ⁻⁶	28.8	1
FR 1	5/2/52	18°13'N 76°27'W	Sfc.	2010	26.2			26.2	1
FR 62	29/8/55	35° 3'N 75°20'W	Sfc.	1150-- 1220				27.0	1
Y 89	4/2/54	17°14'N 83°49'W	Sfc.	1700		36.24		27.4	1
Supl. 2	-/6/52	Matecumbe Key, Fla.	Sfc.						6
Supl. 108	17/7/56	Bimini Harbor	Sfc.	2030-- 2330					2
Supl. 154	20/6/57	25°35'N 79°22'W	Sfc.	0345					1
Longly and Ginsberg		Tortugas							3
USNM 84535 (Albatross 2679)	5/6/1886	32°22'N 76°40'W		2014					2
USNM 84576 (Albatross 2714)	17/9/1886	38°22'N 70°17'W		1658					2
USNM 127487	23/10/1930	Cumberland Sound, Ga.							4
USNM 132959		Habana, Cuba							3

TABLE 1 cont.
Caranx crysos (MITCHILL, 1815). STATION DATA FOR SPECIMENS STUDIED.

Station	Date	Location	Depth M.	Time	Temp. °C	Sal. ‰	Illum.	Sfc. Temp.	No. of Spec.
USNM 133808		New Jersey (Shore)							7
USNM 155286	18/10/37	Bull Bay, S.C.							1
USNM 157577		Clearwater, Fla.							1
USNM 162579		Gulf of Mexico							1
UMML 919	23/7/56	28°20'N 88°37'W							12
NG 29 A	13/7/51	26°08'N 79°56'W	0—60	0845— 0921	27.5	35.99		29.5	2
NG 30 A	2/8/51	"	0—50	0930— 1000	28.0	33.90		29.73	4
NG 31	2/7/51	"	Sfc.	1107	30.81	33.19		30.81	5
NG 32, 7	14/8/51	"	65	1550	24.0		10 ⁻⁰	31.0	1
NG 32, 25	14/8/51	"	75	0330	21.1		10 ⁻⁵	31.0	1
NG 32, 38	14/8/51	"	75	0730	21.1		10 ⁻¹	31.0	1
NG 33	28/8/51	"	68.2	1240— 1310	22.4	36.13		30.35	2
NG 37 B	10/12/51	"	0—50	1240— 1310	25.0	36.10		25.8	1
NG 38 A	1/14/52	"	Sfc.	0940— 1010					3
NG 39 A	2/4/52	"	Sfc.	0945— 1015					1
SL 10, C-0	9/12/52	"	Sfc.	2145	25.72			25.72	1
SL 13, C-0	23/1/53	25°35'N 79°22'W	Sfc.	0030	23.58	36.09		23.58	1

TABLE 1 cont.

Caranx crysos (MITCHILL, 1815). STATION DATA FOR SPECIMENS STUDIED.

Station	Date	Location	Depth M.	Time	Temp. °C	Sal. ‰	Illum.	Sfc. Temp.	No. of Spec.
SL 15, B-0	24/4/53	25°35'N 79°35'W	Sfc.	2255	26.29	35.91	10 ⁻³	26.29	1
SL 16, D-0	21/5/53	"	Sfc.	2035	27.52	36.06	10 ⁻⁴	27.52	2
SL 17, B-7	11/6/53	"	438.7	2200	17.3		10 ⁻⁶	29.56	1
SL 17, F-1	12/6/53	"	67.6	1015	27.3		10 ⁻⁰		1
SL 19, A-1	13/8/53	"	101	1430	26.8		10 ⁻⁵	29.82	3
SL 21, A-1	29/10/53	25°33.3'N 79°23.5'W	68	2150	27.0	36.1		37.32	1
SL 24, A-6	26/3/54	25°35'N 79°22'W	24	0025	24.5	36.2	10 ⁻⁶		1
UMML 1018	23/7/56	28°47'N							3
Oregon 1589		87°56'W							
UMML 1166	22/6/57	Miami, Fla. 9 mi. E							1
UMML 1150	31/8/56	30°16'N							55
Combat, 70		80°21'W							
UMML 22	-/8/55	28°17'N							1
Oregon 1380		88°37'W							
UMML 408	17/11/56	25°18'N							1
		80°20'W							
UMML 1179	17/1/56	25°45'N							
		82°10'W							
SL 37 B-0	8/8/55	26°08'N 79°56'W	Sfc.	1915	27.1		10 ⁺²	27.1	3

TABLE 2

BODILY PROPORTIONS AND COUNTS OF *Caranx crysos* (MITCHILL, 1815)

Source	Std. Length in mm	Head Index	Depth Index	Snout- Head Index	Eye- Head Index	Dorsal Fin	Anal Fin
SL 21, A-1 8841	2.6	38.5	30.8	30.0	30.0	?	?
NG 31 781	2.7	40.7	45.7	22.5	37.5	?	?
NG 31 782	2.8	35.7	32.1	35.0	35.0	?	?
SL 24, A-6 9570	3.8	42.2	39.5	31.2	31.2	?	?
SL 19, A-1 7621	4.0	37.5	37.5	33.3	26.8	?	?
SL 19, A-1 7618	4.1	36.6	39.0	33.3	40.0	VIII-I,12+	II-I,13+
FR 62 14617	4.1	36.6	49.7	40.0	33.3	?	?
SL 37, B-0 18519	4.2	35.7	42.8	26.7	33.3	?	?
NG 38 A 548	4.3	37.2	35.0	31.2	31.2	?	?
SL 40, B-1 18935	4.3	32.5	42.0	43.0	35.7	?	?
NG 38 A 579	4.4	34.1	34.2	40.0	33.3	?	?
SL 13, C-0 3686	4.75	42.2	42.2	40.0	25.0	?	?
SL 16, D-0 6547	4.75	33.8	42.3	37.5	31.3	?	?
NG 33 886	4.9	36.7	47.0	33.3	36.1	VIII-I,17+	II-I,16+
NG 38 A 576	5.0	40.0	32.0	37.5	27.5	?	?
NG 31 784	5.0	40.0	50.0	40.0	32.5	VIII-I,23	II-I,19
NG 33 887	5.1	39.2	47.2	32.3	32.5	VIII-I,21+	II-I,20
NG 32, 38 304	5.2	42.3	54.0	29.5	29.5	VIII-I,20	II-I,17+
NG 32, 25 159	5.3	38.7	58.0	29.3	34.1	VIII-I,19	II-I,15+
SL 16, D-0 6545	5.4	37.1	52.0	29.9	35.0	VIII-I,17+	II-I,17+
SL 17, B-7 6913	5.4	40.7	44.5	35.0	35.0	VIII-I,23	II-I,19
FR 1 1837	5.4	40.7	50.0	31.8	34.0	VIII-I,19+	II-I,19

BODILY PROPORTIONS AND COUNTS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Source	Std. Length in mm	Head Index	Depth Index	Snout- Head Index	Eye- Head Index	Dorsal Fin	Anal Fin
SL 19, A-1 7619	5.45	37.6	46.0	34.1	36.6	VIII-I,20+	II-I,17+
NG 31 783	5.6	41.2	48.5	34.8	32.6	VIII-I,23	II-I,19
SL 16, D-0 6546	5.8	38.0	57.0	27.3	32.7	VIII-I,22+	II-I,18+
SL 10, C-0 2844	5.9	40.7	49.3	25.0	37.5	VIII-I,23	II-I,20
NG 30 A 808	5.9	33.9	45.7	22.5	37.5	VIII-I,20+	II-I,18+
NG 30 A 805	5.9	39.0	45.7	30.4	34.8	VIII-I,23	II-I,19
NG 39 A 1725	6.0	34.0	43.5	43.0	30.9	VIII-I,23	II-I,19
SL 37, B-0 18518	6.2	38.7	43.5	31.2	31.2	VIII-I,23	II-I,19
SL 37, B-0 18517	6.3	38.1	47.6	33.3	35.4	VIII-I,23	II-I,19
SL 37, B-0 18480	6.5	38.5	46.2	32.0	34.0	VIII-I,23	II-I,19
NG 31 785	7.7	39.0	44.2	33.4	33.4	VIII-I,23	II-I,19
SL 15, B-0 5843	7.9	35.5	57.5	25.0	28.0	VIII-I,23	II-I,19
SL 17, F-1 7189	8.5	37.6	48.3	28.1	37.5	VIII-I,24	II-I,21
NG 30 A 807	8.8	38.7	47.7	29.4	35.3	VIII-I,23	II-I,21
NG 29 A 3515	9.2	37.0	50.0	27.9	35.9	VIII-I,24	II-I,20
NG 29 A 3516	9.9	39.4	52.6	25.7	35.9	VIII-I,23	II-I,20
NG 30 A 806	10.0	39.0	50.0	28.2	34.6	VIII-I,23	II-I,20
NG 32 7	10.8	40.7	49.0	36.4	31.8	VIII-I,24	II-I,20
Supl. 2 4481	12.1	41.3	50.4	30.0	34.0	VIII-I,24	II-I,20
Supl. 154 21437	12.3	41.5	48.7	34.4	34.4	VIII-I,24	II-I,21
Supl. 2 4484	12.9	38.7	51.5	20.0	38.0	VIII-I,23	II-I,19
UMML. 1150	13.5	37.0	47.4	30.0	34.0	VIII-I,23	II-I,20
UMML. 1150	13.5	37.0	46.6	28.0	36.0	VIII-I,23	II-I,20
UMML. 1150	14.9	36.2	46.3	26.0	35.2	VIII-I,24	II-I,20

BODILY PROPORTIONS AND COUNTS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Source	Std. Length in mm	Head Index	Depth Index	Snout- Head Index	Eye- Head Index	Dorsal Fin	Anal Fin
UMML. 919	15.1	38.4	45.0	26.9	36.2	VIII-I,23	II-I,19
UMML. 1150	15.1	39.2	47.4	30.6	33.9	VIII-I,24	II-I,19
Supl. 2 4482	16.3	36.8	45.3	27.5	33.4	VIII-I,23	II-I,20
Supl. 2 4483	16.5	36.9	44.1	26.3	26.2	VIII-I,23	II-I,20
FR 62 14616	17.0	39.4	50.0	26.7	34.3	VIII-I,23	II-I,20
UMML. 1150	17.2	37.8	44.2	29.2	32.4	VIII-I,23	II-I,19
UMML. 1150	19.5	33.8	45.1	24.3	33.4	VIII-I,24	II-I,20
Supl. 2 4486	21.3	35.8	39.9	30.5	26.9	VIII-I,23	II-I,20
UMML. 1150	21.5	33.5	42.7	22.2	33.4	VIII-I,24	II-I,20
UMML. 1166	22.5	35.6	44.0	25.6	35.4	VIII-I,24	II-I,20
UMML. 1150	22.6	35.4	42.8	29.8	32.5	VIII-I,24	II-I,20
UMML. 1150	23.3	33.0	42.5	26.0	33.8	VIII-I,23	II-I,19
UMML. 1150	24.0	33.3	40.0	26.3	32.5	VIII-I,24	II-I,20
Supl. 2 4487	24.2	34.3	43.0	30.2	32.5	VIII-I,23	II-I,20
UMML. 1150	24.5	34.2	42.1	27.4	29.8	VIII-I,23	II-I,20
UMML. 1018	24.5	35.5	40.8	32.2	28.7	VIII-I,24	II-I,20
UMML. 1150	24.5	33.2	43.0	24.4	34.1	VIII-I,24	II-I,19
UMML. 1150	24.6	36.1	42.7	30.3	28.1	VIII-I,24	II-I,20
UMML. 1150	24.8	34.6	40.3	32.4	32.4	VIII-I,23	II-I,20
Y 89 1756	25.0	33.6	44.0	29.8	32.2	VIII-I,24	II-I,20
UMML. 919	25.1	34.7	42.0	31.0	33.4	VIII-I,23	II-I,19
UMML. 1150	25.3	34.4	40.3	28.8	29.9	VIII-I,23	II-I,19
UMML. 1150	26.0	34.6	42.4	31.1	30.0	VIII-I,24	II-I,20
UMML. 1150	26.2	36.2	42.0	31.6	26.3	VIII-I,23	II-I,19
UMML. 1150	26.8	35.4	41.1	31.6	28.4	VIII-I,23	II-I,20
UMML. 1150	27.3	35.5	42.2	33.0	30.9	VIII-I,23	II-I,20
UMML. 1150	28.5	33.3	40.7	27.4	31.6	VIII-I,24	II-I,20
UMML. 1150	30.0	33.4	39.4	31.0	31.0	VIII-I,23	II-I,20
UMML. 1150	30.5	36.7	39.4	33.9	26.8	VIII-I,23	II-I,19
Supl. 108 20900	31.5	35.3	37.5	28.8	27.9	VIII-I,24	II-I,20
UMML. 1018	32.6	33.2	36.8	31.5	30.6	VIII-I,25	II-I,20
UMML. 919	35.2	33.0	38.4	28.4	29.3	VIII-I,24	II-I,20
USNM. 84567	36.0	33.4	37.5	29.2	33.2	VIII-I,23	II-I,20
UMML. 1150	36.0	30.6	38.4	29.7	27.3	VIII-I,24	II-I,20
UMML. 919	36.1	34.1	37.7	34.1	28.4	VIII-I,23	II-I,20
UMML. 919	36.3	33.1	37.8	28.3	31.6	VIII-I,24	II-I,20
UMML. 1150	36.5	35.1	38.5	31.5	26.8	VIII-I,24	II-I,20

BODILY PROPORTIONS AND COUNTS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Source	Std. Length in mm	Head Index	Depth Index	Snout- Head Index	Eye- Head Index	Dorsal Fin	Anal Fin
UMML. 919	37.0	32.4	37.8	29.2	29.2	VIII-I,24	II-I,20
USNM. 84567	37.0	35.2	37.8	30.7	30.8	VIII-I,24	II-I,20
UMML. 1150	37.3	34.1	38.4	31.8	29.1	VIII-I,23	II-I,20
Supl. 108 20901	38.3	34.5	36.4	32.6	28.0	VIII-I,23	II-I,19
UMML. 1150	38.3	33.4	37.9	30.5	30.1	VIII-I,24	II-I,20
UMML. 919	38.5	31.4	34.8	28.9	26.4	VIII-I,24	II-I,20
UMML. 1018	38.5	32.0	36.6	30.0	31.7	VIII-I,24	II-I,21
UMML. 1150	38.9	32.9	34.7	30.5	25.2	VIII-I,23	II-I,19
UMML. 1150	39.5	33.2	35.5	34.0	22.9	VIII-I,23	II-I,21
UMML. 1150	40.1	33.0	33.9	37.9	28.5	VIII-I,22	II-I,20
UMML. 1150	40.3	31.8	36.0	29.6	24.4	VIII-I,23	II-I,19
UMML. 919	41.0	31.7	36.4	34.6	29.2	VIII-I,23	II-I,20
UMML. 919	41.8	33.2	35.9	28.8	31.7	VIII-I,24	II-I,20
UMML. 919	41.8	31.1	36.6	30.0	30.0	VIII-I,23	II-I,20
UMML. 1150	41.8	32.7	36.4	31.2	25.7	VIII-I,23	II-I,21
UMML. 1150	41.9	31.8	33.7	30.0	27.1	VIII-I,24	II-I,19
UMML. 1150	42.2	32.0	35.6	31.5	25.9	VIII-I,23	II-I,20
UMML. 1150	42.4	33.1	37.8	30.3	26.5	VIII-I,23	II-I,20
UMML. 1150	42.7	31.6	37.4	31.5	22.9	VIII-I,22	II-I,19
UMML. 1150	43.0	32.2	37.3	29.3	26.4	VIII-I,23	II-I,20
UMML. 1150	44.0	32.7	37.0	30.0	23.6	VIII-I,23	II-I,19
UMML. 1150	44.6	31.4	35.4	30.9	24.2	VIII-I,23	II-I,20
UMML. 1150	44.9	31.2	35.7	30.7	26.4	VIII-I,24	II-I,19
USNM. 84535	45.0	31.1	37.8	32.2	28.6	VIII-I,24	II-I,20
UMML. 1150	45.5	30.8	35.2	30.0	26.4	VIII-I,24	II-I,21
UMML. 1150	46.0	31.5	34.0	28.3	24.1	VIII-I,23	II-I,20
UMML. 1150	46.8	31.0	36.7	31.0	25.3	VIII-I,24	II-I,20
UMML. 1150	46.9	30.8	35.6	28.7	25.9	VIII-I,23	II-I,21
UMML. 1150	47.9	32.0	34.8	29.4	25.5	VIII-I,23	II-I,19
USNM. 84535	48.0	31.3	35.5	26.6	26.6	VIII-I,24	II-I,20
UMML. 1150	48.2	31.8	33.6	31.4	23.5	VIII-I,23	II-I,20
UMML. 1150	48.5	35.0	36.1	30.6	25.0	VIII-I,24	II-I,20
UMML. 919	48.5	31.4	35.5	32.2	26.3	VIII-I,23	II-I,19
UMML. 1150	50.0	30.6	36.0	30.7	26.8	VIII-I,23	II-I,20
UMML. 1150	51.5	32.1	36.0	30.9	24.2	VIII-I,24	II-I,20
UMML. 1150	53.0	30.8	34.2	30.6	24.5	VIII-I,23	II-I,20
UMML. 1150	54.7	30.7	34.8	29.7	24.4	VIII-I,23	II-I,20
UMML. 1150	55.7	30.0	33.9	29.9	25.1	VIII-I,24	II-I,19
UMML. 1150	59.3	29.5	34.1	30.3	24.0	VIII-I,23	II-I,19
UMML. 1150	59.3	30.7	35.0	30.2	26.9	VIII-I,23	II-I,20
UMML. 1150	62.3	29.2	34.0	30.2	24.7	VIII-I,23	II-I,20

BODILY PROPORTIONS AND COUNTS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Source	Std. Length in mm	Head Index	Depth Index	Snout- Head Index	Eye- Head Index	Dorsal Fin	Anal Fin
UMML. 919	64.5	30.1	33.0	30.9	23.2	VIII-I,24	II-I,19
UMML. 22	79.0	29.1	34.1	29.7	23.1	VIII-I,23	II-I,20
Ore. 1380							
USNM. 133808	85.5	29.2	32.2	28.0	22.0	VIII-I,23	II-I,20
USNM. 133808	90.0	27.2	31.7	32.6	24.9	VIII-I,24	II-I,20
USNM. 133808	90.0	27.8	33.4	32.0	24.0	VIII-I,23	II-I,20
USNM. 133808	91.0	27.5	31.8	28.9	24.0	VIII-I,23	II-I,19
UMML. 1150	95.0	28.4	32.1	29.2	25.2	VIII-I,23	II-I,19
USNM. 133808	95.0	27.9	32.7	30.0	22.7	VIII-I,23	II-I,20
USNM. 133808	96.0	27.1	31.4	30.7	25.0	VIII-I,23	II-I,20
USNM. 133808	98.0	29.6	32.6	31.0	22.4	VIII-I,24	II-I,20
Longley & Ginsburg	106.0	29.2	31.1	29.0	19.4	?	?
Longley & Ginsburg	114.0	26.3	30.7	30.0	20.0	?	?
Longley & Ginsburg	117.0	27.4	31.6	31.3	18.8	?	?
USNM. 155286	126.0	29.8	34.1	32.4	23.0	VIII-I,24	II-I,20
USNM. 127487	127.0	29.1	32.2	29.7	21.6	VIII-I,?	II-I,?
USNM. 132959	128.0	27.3	34.3	34.3	20.0	VIII-I,23	II-I,20
USNM. 132959	130.0	28.4	31.1	31.1	21.6	VIII-I,23	II-I,20
USNM. 127487	131.0	28.2	32.0	29.8	21.6	?	?
USNM. 127487	134.0	28.3	29.9	30.3	23.6	VIII-I,23	II-I,20
UMML. 1179	135.0	31.2	31.5	29.0	25.0	VIII-I,24	II-I,20
USNM. 132959	141.0	29.0	31.7	31.7	19.5	VIII-I,23	II-I,20
USNM. 127487	153.0	30.0	31.4	32.6	19.5	?	?
UMML. 408	163.5	29.4	34.8	29.2	26.7	VIII-I,23	II-I,20
USNM. 157577	221.0	27.0	28.0	32.0	17.6	VIII-I,24	II-I,20
USNM. 162579	247.0	27.1	28.8	29.8	16.4	VIII-I,24	II-I,20

length was not taken. All measurements are expressed in millimeters.

Standard Length is measured from the tip of the snout to the tip of the vertebral column until the appearance of the hypural plate. Once the plate is formed, the measurement is taken from the tip of the snout to the middle of the caudal base. When length is referred to or implied by such words or phrases as "size," "size groups," or "size range" the reference is to standard length.

Head Length is measured from the tip of the snout to the most posterior edge of the fleshy opercle. In some smaller specimens this flap was not noted and in such cases the measurement was to the edge of the bony opercle.

Depth, before the appearance of the pelvic fins, is measured from the lowest point of the gut in a direct vertical line to the dorsal outline of the body; it does not include the fin folds. Once the pelvic fins appear, the measurement is taken from the angle of the pelvic base in a direct vertical line to the dorsal outline of the trunk.

Snout Length is measured from the tip of the upper jaw to the anterior edge of the bony orbit.

Eye Diameter is measured horizontally from the anterior inside edge of the bony orbit to the posterior inside edge of the orbit.

Fin-Ray Counts include only fully formed rays. For the specimens below 7 mm, fin-ray counts are given when such counts were possible. In some specimens the posterior rays of the dorsal and anal fins were not yet formed. This was true of some specimens between 5.5 mm and 6.0 mm in length. In specimens where the fins were damaged or the rays were difficult to distinguish the counts were not recorded.

Indices are percentages of standard length or head length and were computed with a standard professional slide rule.

Measurements and indices of all specimens studied are given in Table 2.

LARVAL DEVELOPMENT

2.6 mm specimen (Figure 1a).

The smallest specimen examined is an early postlarva. The head is large, 38.5 per cent of standard length with a sharply demarcated, upturned snout, 30.0 per cent of head length. The nares have not appeared. The mouth is large, nearly vertical, and several small teeth or spikes are present on the jaws. Although the eye is relatively large, 30.0 per cent of the head length, its size is not exceptional for a larva

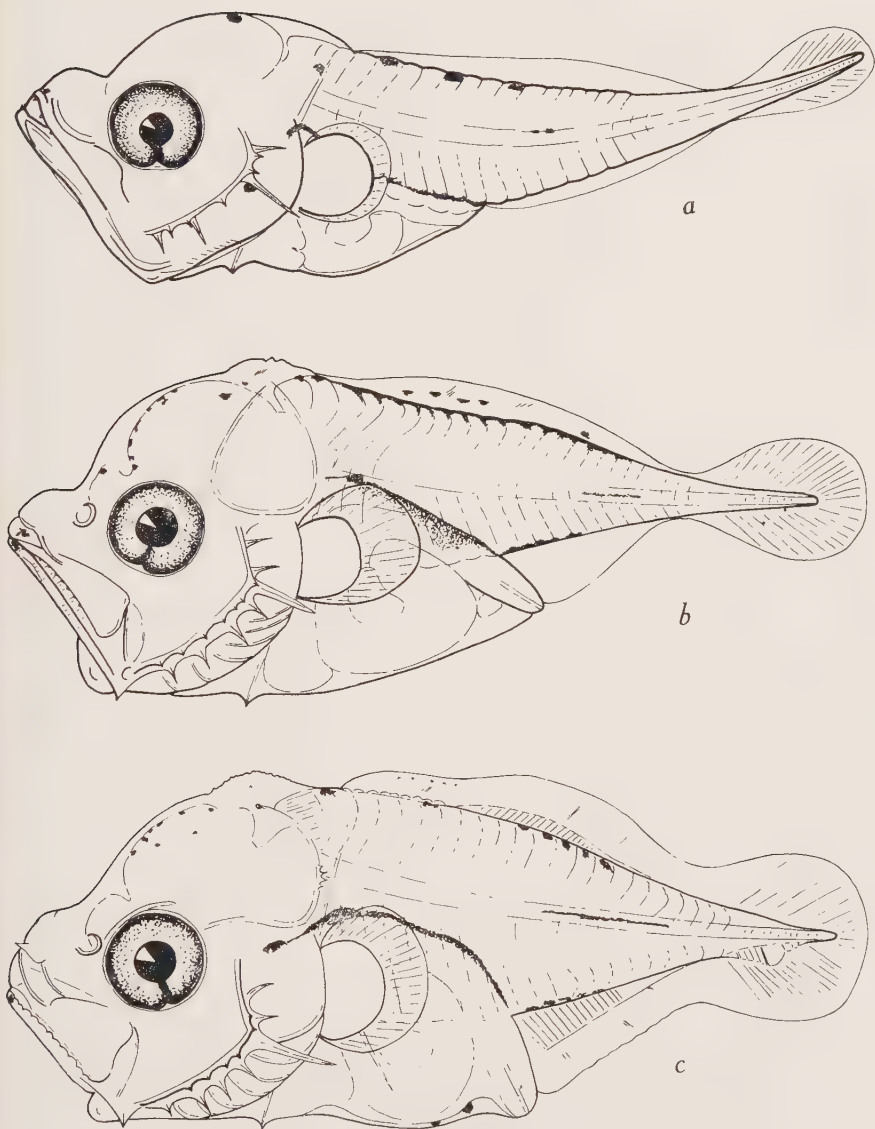


Figure 1. *Caranx crysos* (Mitchill). a. 2.6 mm standard length (SL-21, A-1), b. 3.8 mm standard length (SL-24, A-6, 9570), c. 4.2 mm standard length (SL-37, B-0, 18519).

at this stage. The occipital crest, which later becomes prominent, is not well developed. There are two rows of spines along the preopercle; the innermost row is by far the larger, and its largest spine is at the angle of the preopercle. The sac-like gut ends in a posteriorly directed anus. Fin folds were difficult to distinguish in this specimen although the caudal portion was clearly visible. The pectorals are prominent, but are largely composed of the fleshy base. Ventrally a portion of the pelvic girdle can be seen just beneath the opercle.

Pigmentation is present along the dorsal surface of the gut and the dorsal part of the body. Pigment spots are also present on the cranium, at the angle of the preopercle and in the region of the vertebral column about half way between the head and the caudal region.

3.8 mm specimen (Figure 1b).

Considerable change has occurred over a size increase of 1.2 mm. The depth of the head at the anterior portion of the body has increased to 39.5 per cent of standard length. The snout is similar in appearance to the 2.6 mm specimen and only slightly larger, 31.2 per cent of head length; however, the bones forming the snout are better developed. The head length has increased to 42.2 per cent of standard length. The nares are present but are not yet perforate. The mouth is nearly vertical and the number of teeth on the upper jaw has increased. The eye is 31.2 per cent of head length. At this stage the crest in the occipital region is quite well developed with a somewhat serrate edge. The preopercular spines have not only increased in number but also in size. The gut shows an increase in relative size and the anus has turned somewhat ventrally. The fin fold is higher and definitely continuous in the caudal region. The pectorals are about the same relative size, but the portion occupied by the fleshy base has decreased.

Pigmentation is in general similar to that described for the 2.6 mm specimen but is more extensive. Melanophores have also appeared on the dorsal fin fold and on the tip of the snout. There is also an extension of the pigment ventrally, posterior to the anus.

4.2 mm specimen (Figure 1c).

At this size the anterior increase in depth noted in the previous specimen has not only extended posteriorly, but has increased to 42.8 per cent of standard length. The snout is less upturned than in the former two specimens and is now 26.7 per cent of the head length. The mouth is less oblique and the spines along the upper jaw now present a more serrate appearance. The eye is only slightly larger.

The head length is 35.7 per cent of standard length. No change in either the nares or the crest is apparent. The preopercular spines have increased to about their maximum size while a small patch of minute spines has appeared on the posterior portion of the head. The anus is directed still more ventrally than in the former specimen but otherwise the gut shows no significant change.

Besides the change in body shape due to increase in depth, and the rounding of the snout, the fins also show a marked change. The fin fold has increased considerably in height. Developing soft rays can be seen in the region of the dorsal and there are indications of the dorsal spines. In the caudal region the hypural plate has begun to form. The pectoral fins are slightly larger than those of the preceding specimen.

Pigment pattern has not changed to any great extent. The spots present in the dorsal fin fold are barely noticeable in this specimen and some pigment is now present on the belly. The amount of pigment along the vertebral column has increased.

6.2 mm specimen (Figure 2a).

This specimen shows considerable differences from the preceding one. The animal is deepest about midway of its length and tapers rather sharply towards both ends. Depth is still increasing and is now 47.6 per cent of standard length. The snout is more rounded, but it still shows some protrusion and the mouth is less vertical than before. The snout is 33.3 per cent of head length and the head is about 38.1 per cent of standard length, both showing an increase of relative size. The eye is now 35.4 per cent of head length, an increase of 2.1 per cent over the preceding specimen. The serrations along the upper jaw are disappearing. The double structure of the nares is now apparent. In the occipital region the crest is still present, but has decreased in relative size. The preopercular spines also show a slight decrease in relative size and the patch of spines on the posterior part of the head above the upper limb of the opercle is slightly more developed. The anus is directed almost ventrally and the tissues over the gut cavity have thickened so that the detail of the gut can no longer be ascertained.

Nine spines are now present in the dorsal fin and three in the anal, all of them appearing more stout than in the adult. The soft dorsal and anal are high and rounded. The hypural plate is completely formed and the caudal fin is truncate. The pectoral fin is slightly more elongate. The pelvics have appeared but are still small and poorly developed.

True chromatophores have appeared on the head and sides and in

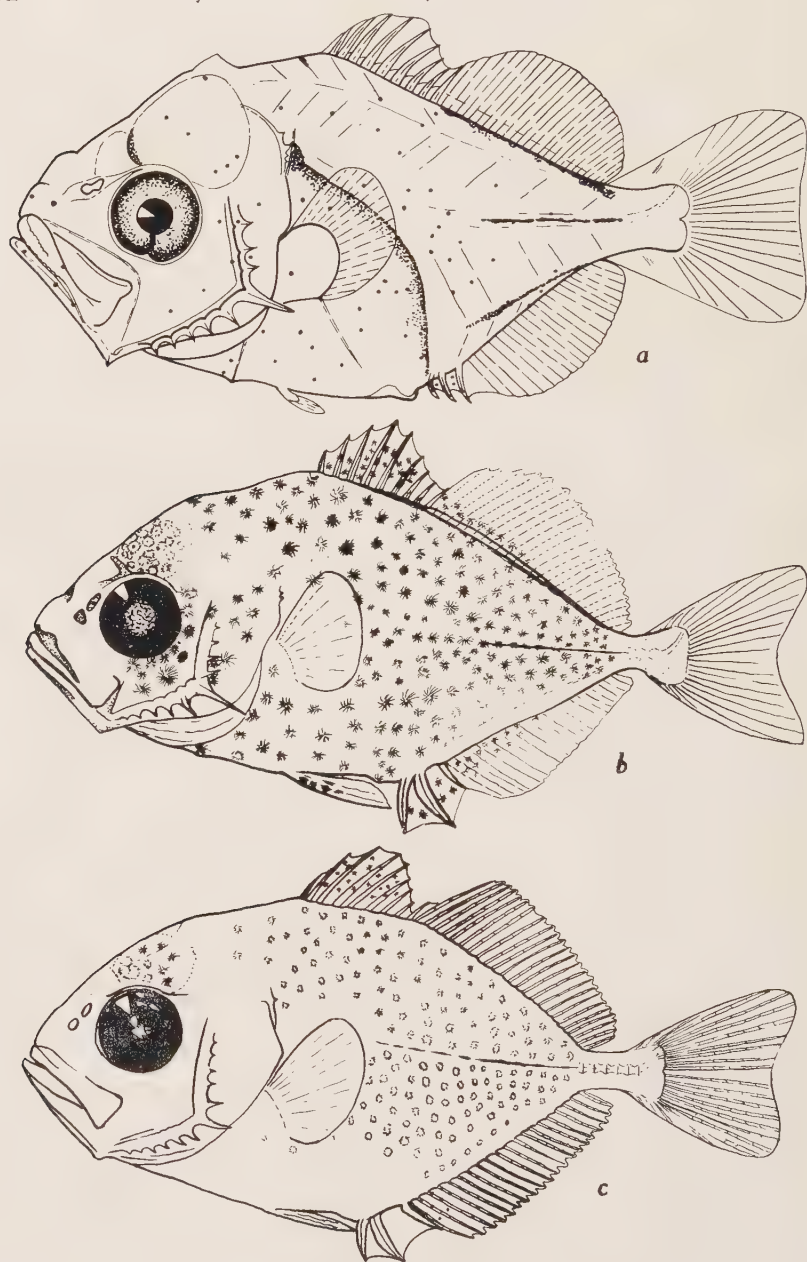


Figure 2. *Caranx crysos* (Mitchill). a. 6.2 mm standard length (SL-37, B-0, 18517), b. 8.5 mm standard length (SL-17, F-1), c. 9.9 mm standard length (NG-29A).

most specimens they are more expanded than in the specimen shown in Figure 2a. The fins are unpigmented with the exception of several chromatophores on the spiny section of the anal.

8.5 and 9.9 mm specimens (Figures 2b and c).

By the time the animal is about 6.0 mm in length all of the essential structures which will be found in the adult are present in various stages of development. Specimens from about 8.5 mm to 12.0 mm are in a transitional stage at about the end of the postlarval period of development. The specimens illustrated in Figures 2b and 2c show a general rounding of many of the sharp angles present in the outline of the 6.2 mm specimen, even though the depth is still increasing, attaining 52.6 per cent in the 9.9 mm specimen. Head length is essentially the same as in the 6.2 mm specimen. The protruding character of the snout found in the smaller specimens is less evident, and the snout length is decreasing relatively. The eye diameter reached its maximum of 37.5 per cent in the 8.5 mm specimen. The serrations along the upper jaw are no longer present, the patch of spines at the posterior part of the head has nearly disappeared, and the preopercular spines are becoming relatively shorter. The nares are definitely double and although the mouth is still large it is only slightly more oblique than in the adult. The caudal peduncle is now well differentiated.

Both the soft dorsal and the anal are lower and while both are connected with the first spiny section of the fins the demarcation is more distinct. The dorsal spines reach their maximum relative length in the 8.5 mm specimen. The pelvics show more development and extend to the anus. The caudal fin is less truncate and somewhat smaller in relative size.

Chromatophores cover the 8.5 mm specimen with the exception of the snout, caudal peduncle, and the fins although there is some slight pigmentation on the dorsal, anal, and pelvics. The 9.9 mm specimen is similar but with slightly less pigmentation on the ventral portion.

16.3, 25.0 and 38.3 mm specimens (Figures 3a, b, c).

These may all be considered juveniles. From about 16 mm on the length seems to increase at a faster rate than the other parts and thus the other characters show a decrease in most of the indices. Head length shows a slight decrease to 34.5 per cent in the 38.3 mm specimen. The most marked change is in depth which has decreased from 52.6 per cent in the 9.9 mm specimen to 36.4 per cent in the specimen of 38.3 mm. Eye diameter also shows a decrease in relative size and



Figure 3. *Caranx crysos* (Mitchill). a. 16.3 mm standard length (Supl. 2), b. 25.0 mm standard length (Y 89), c. 38.3 mm standard length (Supl. 108, 20901).

snout length is increasing. The mouth is now only slightly oblique and is relatively smaller. The preopercular spines and the spines on the posterior part of the head have nearly disappeared by the time the fish has reached a length of 38.3 mm.

The first and second dorsal are still continuous but the first and second anal have separated by the time the fish reaches 38 mm. At 25 mm the second dorsal and anal are higher anteriorly and the fin edge more falcate; this is very marked in the 38.3 mm specimen. In the 16.3 and 25.0 mm specimens the pelvics extend to the anal spines but as the fish grows they become relatively shorter. The caudal fin becomes increasingly forked and in the 38.3 mm specimen there is also a relative increase in the length of the lobes. The pectoral fins are more tapered and in the 38.3 mm specimen they are almost pointed.

Scales first appear at a length between 10.0 and 16.0 mm. They are difficult to see at first and are never very large. The lateral line and scutes also become visible in this size range. In the 16.3 and 38.3 mm specimens the lateral line is more highly arched anteriorly than at later, more elongate stages.

In the size range from 16.0 to 38.0 mm a definite color pattern emerges. At 16.3 mm there is a concentration of pigment dorsally on the body, and there is some on the dorsals, the second anal, the caudal and the pectoral fins. At 25 mm a barred pattern is evident. This usually consists of 6-8 (normally 7) dark bands marked off by narrower light areas. At the posterior end of the body these dark bands tend to run together somewhat and are less distinct than anteriorly. Between 25 mm to 38.3 mm a black spot appears on the upper limb of the opercle. The large punctuations mentioned by Nichols (1938, 1939) are present in considerable numbers in the 16.3 and 25.0 mm specimens. However, as the fish grows these become more indistinct and nearly disappear.

59.3 and 135.0 mm specimens (Figures 4a, b).

The specimen of 59.3 mm is a late juvenile, and has acquired nearly all of the characters and appearance of the adult. The second dorsal and anal have their definitive shape and the caudal is more deeply forked. The pectorals are somewhat longer and more pointed.

The dark spot on the opercle is more pronounced and there is less banding in evidence on the sides of the body.

The 135.0 mm specimen is a small adult. The relative head length has increased slightly but the depth of the body has decreased. Both eye

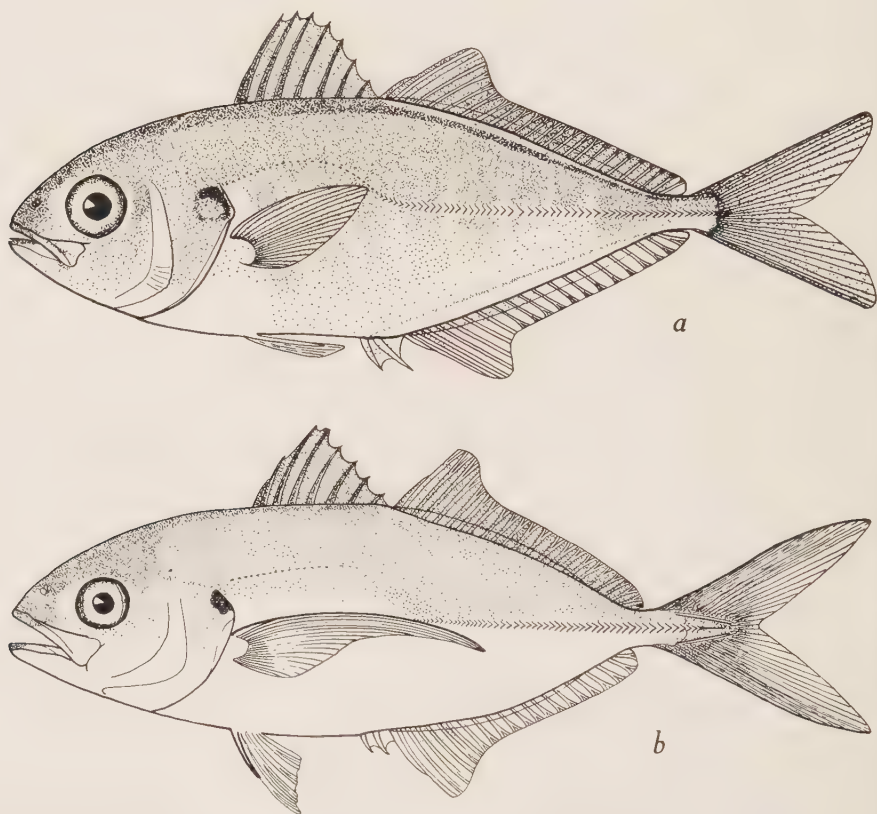


Figure 4. *Caranx crysos* (Mitchill). a. 59.3 mm standard length (UMML 1150), b. 135.0 mm standard length (UMML 1179).

diameter and snout length have decreased slightly in head length. Some time prior to this specimen two small keels appear above and below the scutes in the caudal region. Both the pectoral and the caudal are now greatly elongated, the former having attained its adult sickle shape. The anal spines are less conspicuous than before and become even more so as the fish continue to grow.

The reader is referred to Evermann and Marsh (1902) for a figure of the adult fish and its coloration.

General Development. Figures 5 and 6 are graphs showing changes occurring during the development of *Caranx crysos*. These, as well as the figures of the specimens, indicate that rather marked changes in structure occur at two points during development. The first and most

definite change occurs at approximately 8-12 mm in standard length. The second and less well marked change occurs at a length of 45-60 mm.

Head length, in relation to standard length, is at a maximum in the 2.6-10 mm group, although it varies considerably from 32 to 43 per cent and thereafter decreases until the specimen is about 60-70 mm after which the head length maintains an average of about 27-30 per cent of standard length. There seems to be a slight rise in head length again at 140 mm, but this may be due to lack of sufficient material in the larger size groups.

The snout, which protruded in the smallest specimens, becomes rounded at about 10 mm. The snout index shows a general tendency to decrease from a high in the smallest specimen of about 40 per cent to a low of about 27 per cent. At about 25-30 mm in length the snout index increases slightly to about 30 per cent of head length and remains at this proportion thereafter with little variation.

One of the most striking features of the development of the blue runner is the change in body depth accompanying growth. From a low of about 31 per cent in the smallest specimen there is a rapid increase to about 55 per cent and even higher at a size of about 8 mm and then a gradual decline to about 32 per cent at a length of about 60 mm. The peak of the depth curve probably represents the postlarval peak of development. Accompanying this is a relative increase in the size of the gut cavity, mainly shown by a dorsal and ventral growth of the gut, so that the anus, at first directed almost directly posteriorly, becomes ventrally directed.

Eye diameter, when compared with head length, seems to increase as snout length decreases. From a high of about 37 per cent it decreases rather rapidly to about 25 per cent and then more slowly to as low as 16 per cent of head length in the largest specimen.

Nichols (1938, 1939) lists measurements and properties for eight different size groups of this species, as well as measurements for single specimens of 22 mm and 72 mm.

The authors converted his findings to per cent of standard length or head length for the following: depth in standard length, head in standard length and eye in head length. Nichols' averages were compared with the averages of the authors' specimens falling within the same size groupings by plotting both averages on graph paper. The results of this comparison are very close. The greater differences occurred in the

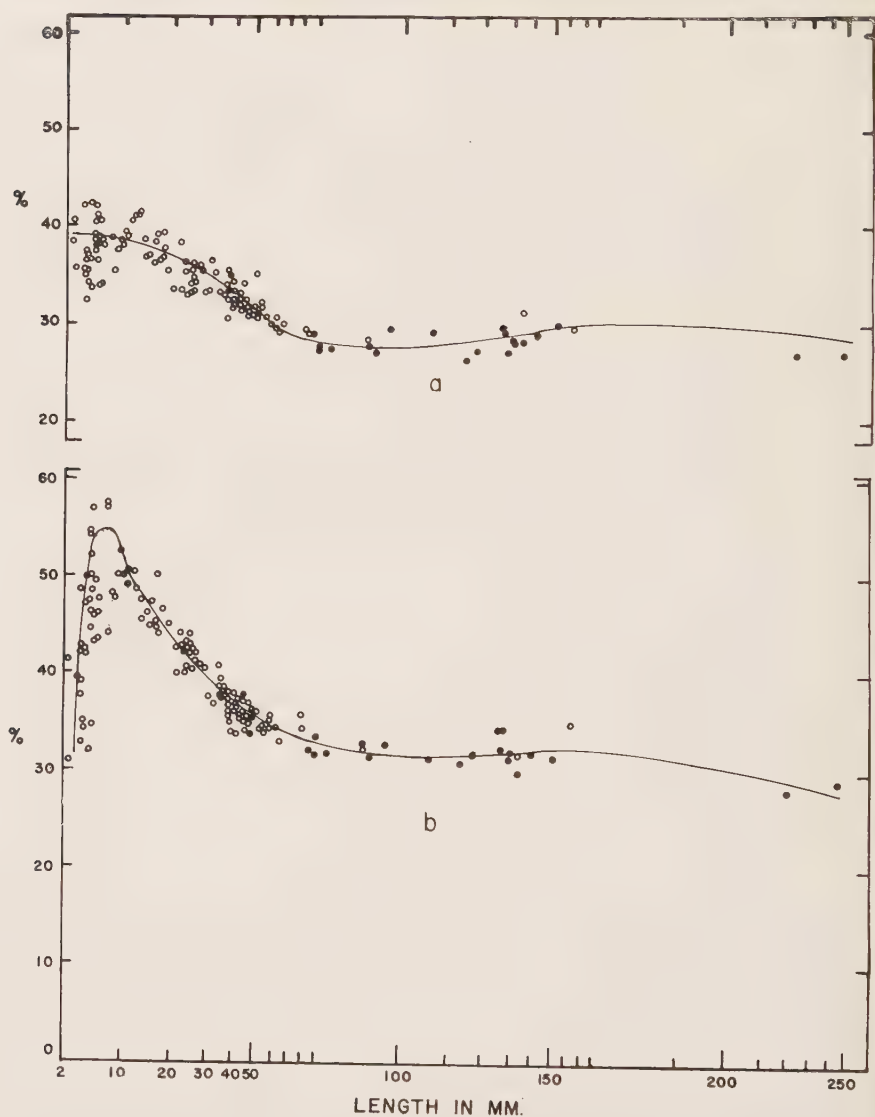


Figure 5. *Caranx crysos* (Mitchill). Change of bodily proportions during growth. a. Relationship of head length to standard length; b. relationship of depth to standard length. Open circles, Marine Laboratory specimens; solid circles, USNM specimens.

largest size group of 170-311 mm. The authors had only two specimens in this group to Nichols' eight. All three curves are very much like

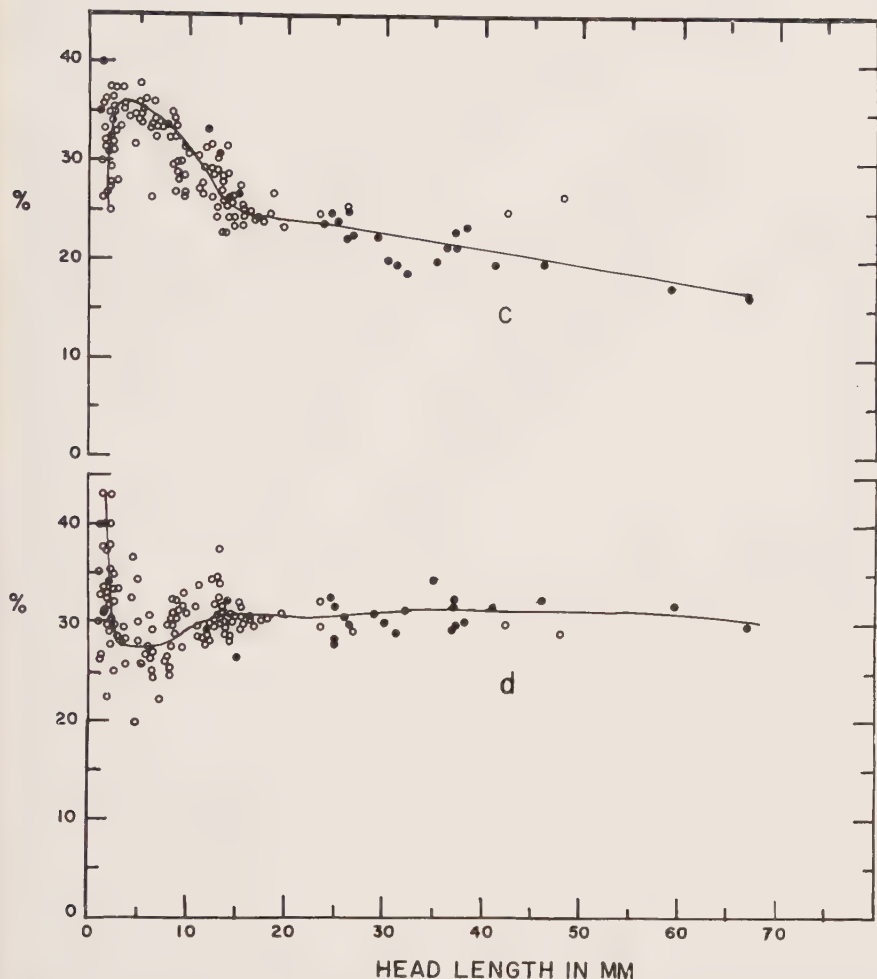


Figure 6. *Caranx crysos* (Mitchill). c. Relationship of eye diameter to head length; d. relationship of snout length to head length. Open circles, Marine Laboratory specimens; solid circles, USNM specimens.

those presented by Nichols' specimens.

The almost vertical mouth found in the smaller specimens gradually becomes oblique and at about 10.0 mm standard length, it has assumed the position that it will maintain throughout life.

Preopercular spines are present in the smallest specimen and reach their greatest relative size in the 4.0-5.0 mm group and then decline in

importance and are barely noticeable in specimens 40 mm in length.

In specimens 5.0-6.0 mm in length the fins are all present in their essential structures although there is considerable change in their shape before the adult form is attained. In some specimens the last rays of the dorsal and anal were not formed until the animal was 6.0 mm long but in one specimen of 5.0 mm all rays were present. One specimen 40.1 mm in length had only 22 dorsal rays.

The dorsal and anal fins attain the shape present in the adult by the time the fish is 25-40 mm long although the spines of the dorsal and anal are still somewhat longer and wider than in the adult. The caudal attains its definitive shape when the fish is about 90 mm in length. At the same time the fleshy keels on the caudal peduncle are noticeable. The pectorals become slightly falcate in specimens 50-60 mm long but they do not fully develop this feature except in specimens over 100 mm.

The procumbent dorsal spine attributed to these fishes appears in the 6.1 mm specimen just anterior to the first upright dorsal spine. At this size it is only slightly angled anteriorly, but in the 8.7 mm specimen it has a very definite anterior projection. It may be seen or at least felt with a probe in all large specimens, even the adults. Following a suggestion of Dr C. Richard Robins a specimen of about 4.0 mm standard length was dissected and the procumbent spine was found to be an interneural spine as Robins had suggested.

Pigmentation first appears on the crown of the head, along the dorsal part of the body, around the gut cavity, and the middle of the sides. The pattern does not change, with the exception of some pigment on the snout, the dorsal fin fold and on the belly, until a size of about 5.5-6.0 mm is attained, when chromatophores appear all over the head and body. At 10.0 mm there is a noticeable dorsal concentration and at 25 mm a barred pattern is evident. This becomes more noticeable and reaches its fullest development at about 40.0 mm when 6 to 8, usually 7, bands are evident. The first starts just below the first dorsal spine and the last ones tend to run together on the caudal peduncle. The large pigment spots described by Nichols (1939) are present up to a size of about 60 mm on the upper parts but are obscured beyond a length of 38 mm by the heavy dorsal concentration of pigment. From about 25-30 mm standard length the large spots break up and become somewhat obscured. The beginning of a banded pattern can be seen in some specimens at about 14 mm, although bands often are not present in specimens as large as 20 mm. Specimens larger than 20 mm all

showed a banded pattern. In some, this pattern was quite faint (See Nichols, 1938, fig. 1) but in others it was very clear (Figure 3c). These bands have nearly disappeared in fish with a length of 60 mm. The black spot on the opercle was clearly evident at about 30-35 mm but before this most specimens had a concentration of pigment in this area which, however, was often difficult to detect.

Evidently the method of preservation and perhaps the manner of death affect the intensity of the color pattern and possibly the pattern itself. Specimens in alcohol show the color pattern better than those in formalin. Furthermore, those specimens with a gaping mouth and expanded gill covers, indicating that death occurred before they were placed in the preservative, had a much fainter pattern than the others.

Adult specimens of *Caranx crysos* also exhibit a pattern of dark bands when alive. This is usually a very subtle and shadowy pattern, but may be distinct and striking in some instances. It disappears at death and none of the preserved specimens examined exhibited it. This pattern may be associated with stress, since it frequently appears on specimens caught with hook and line before they die.

BIOLOGY

Spawning. Since the present study is based mainly upon the collections of larval and juvenile blue runners in The Marine Laboratory collection few adult fish were available for gonad examination, and time of spawning could not be ascertained by this method.

Instead, all of the postlarval specimens, from 2.6 to 16 mm, were ranked in 1 mm size groups and plotted against month of capture. Examination of Table 3, based upon 50 specimens, reveals that postlarvae have been taken in every month except September and November. Although the specimens are too few to give conclusive information, it appears that spawning may occur throughout the year, as has been found for many of the tropical fish so far studied. However, the table also suggests that the main spawning takes place from January through August with a somewhat higher activity during the peak of the summer. About 75 per cent of all of the postlarvae were taken during the period from April through August.

Food. All of the specimens examined, with the exception of the USNM material, were dissected in order to obtain data on stomach contents. Most specimens had food in various stages of digestion in the gut and all material was identified at least to general groups. The results of this study are presented in Table 4.

TABLE 3

DISTRIBUTION BY MONTH OF POSTLARVAL SPECIMENS OF *Caranx crysos* (MITCHILL, 1815)

Std. Length in mm.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
2-3							2		1			
3-4			3									
4-5	3				1			5	1			
5-6	1	1			2	2	2	6			1	
6-7				1				3				
7-8				1			1					
8-9						1		1				
9-10							1					
10-11								2				
11-12						1						
12-13						2						
13-14								2				
14-15								1				
15-16							1	1				
Total Specimens per month	4	1	3	2	3	6	7	21	0	2	0	1

TABLE 4

STOMACH CONTENTS OF POSTLARVAL AND JUVENILE
SPECIMENS OF *Caranx crysos* (MITCHILL, 1815)

Standard Length in mm	Stomach Contents	Standard Length in mm	Stomach Contents
2.6	Empty	9.2	15 Cyclopoid copepods
2.7	1 Cyclopoid copepod	9.9	20 Cyclopoid copepods
2.8	Empty	10.0	1 Calanoid copepod, 9 Cyclopoid copepods
3.8	Empty		
4.0	Empty		
4.1	3 Cyclopoid copepods	10.8	7 Calanoid, 25 Cyclopoid, 4 Harpacticoid copepods
4.1	Fragments of copepods		
4.2	4 Cyclopoid copepods	11.5	17 Calanoid, 12 Cyclopoid copepods
4.3	Empty		
4.3	2 Cyclopoid copepods	11.7	4 Calanoid, 12 Cyclopoid copepods
4.4	4 Cyclopoid copepods		
4.75	Empty	12.1	75 Cyclopoid copepods
4.75	4 Cyclopoid copepods	12.3	Fragments of copepods
4.9	3 Cyclopoid copepods		
5.0	3 Cyclopoid copepods	12.9	25 Cyclopoid copepods, 1 Ostracod, 3 Eggs
5.0	1 Cyclopoid copepod		
5.1	2 Cyclopoid copepods	13.5	Empty
5.2	2 Cyclopoid copepods	13.5	2 Cyclopoid copepods
5.3	Empty	14.9	2 Cyclopoid copepods
5.4	4 Cyclopoid copepods, many fragments	15.1	Empty
5.4	Fragments of copepods	15.8	5 Cyclopoid copepods
5.4	Empty	16.3	1 Calanoid, 50 Cyclopoid copepods, 4 Harpacticoid copepods
5.45	Empty		
5.5	1 Cyclopoid copepod	16.5	1 Calanoid, 93 Cyclopoid, 4 Harpacticoid copepods, 20 Eggs
5.6	4 Cyclopoid copepods		
5.8	Empty		
5.9	2 Cyclopoid copepods, many fragments	17.0	6 Calanoid, 125 Cyclopoid copepods, 4 Eggs
5.9	Empty		
5.9	4 Cyclopoid copepods	17.2	1 Calanoid, 20 Cyclopoid copepods
6.0	3 Cyclopoid copepods		
6.2	10 Cyclopoid copepods	18.0	110 Cyclopoid copepods
6.3	14 Cyclopoid copepods	19.5	Empty
6.5	6 Cyclopoid copepods		
7.7	4 Cyclopoid copepods	21.3	1 Calanoid, 200 Cyclopoid, 3 Harpacticoid copepods, 13 Eggs
7.9	Fragments of copepods		
8.5	2 Calanoid copepods, 4 Cyclopoid copepods	21.5	Empty
8.8	8 Cyclopoid copepods	22.5	200 Cyclopoid copepods, plus many fragments

STOMACH CONTENTS OF POSTLARVAL AND JUVENILE
SPECIMENS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Standard Length in mm	Stomach Contents	Standard Length in mm	Stomach Contents
22.6	Empty	36.0	5 Calanoid, 3 Cyclopoid copepods, plus fragments
23.3	10 Cyclopoid copepods		
24.0	4 Calanoid, 20 Cyclopoid copepods	36.1	Empty
24.2	1 Calanoid, 225 Cyclopoid, 2 Harpacticoid copepods, 10 Eggs	36.3	Empty
		36.5	5 Calanoid copepods
		37.0	Empty
24.5	1 Calanoid, 20 Cyclopoid copepods	37.3	2 Calanoid, 1 Cyclopoid copepods, plus fragments
24.5	1 Calanoid, 15 Cyclopoid copepods	38.3	7 Calanoid copepods, plus fragments
24.5	1 Calanoid copepod	38.3	Empty
24.6	7 Calanoid, 9 Cyclopoid copepods	38.5	Empty
		38.5	Empty
24.8	8 Calanoid, 15 Cyclopoid copepods	38.9	40 Calanoid, 3 Cyclopoid copepods
25.0	3 Calanoid copepods, fragments	39.5	3 Calanoid, 7 Cyclopoid copepods, plus fragments
25.1	Empty	40.1	53 Calanoid, 8 Cyclopoid copepods, plus fragments, 1 Decopod larva
25.3	5 Calanoid copepods		
26.0	13 Calanoid, 10 Cyclopoid copepods	40.3	8 Calanoid, 11 Cyclopoid copepods, plus fragments
26.2	Empty		
26.8	3 Calanoid, 7 Cyclopoid copepods	41.0	Empty
		41.8	Empty
27.3	Empty	41.8	Empty
28.5	5 Calanoid, 4 Cyclopoid copepods	41.8	3 Calanoid, 3 Cyclopoid copepods plus fragments
30.0	4 Calanoid, 8 Cyclopoid copepods		
30.5	4 Calanoid, 7 Cyclopoid copepods	41.9	51 Calanoid, 10 Cyclopoid copepods plus fragments
31.5	1 Calanoid copepod	42.2	Empty
32.6	1 Calanoid, 1 Cyclopoid copepods, plus fragments	42.4	5 Calanoid, 4 Cyclopoid copepods plus fragments
35.0	150 Calanoid, 263 Cyclopoid copepods, 2 Amphipods, 8 Eggs, 2 Ostracods	42.7	11 Calanoid, 7 Cyclopoid copepods
		43.0	1 Calanoid copepod
		44.0	16 Calanoid copepods, 2 Larval fish unidentified
35.2	Empty		

STOMACH CONTENTS OF POSTLARVAL AND JUVENILE
SPECIMENS OF *Caranx crysos* (MITCHILL, 1815) (cont.)

Standard Length in mm	Stomach Contents	Standard Length in mm	Stomach Contents
44.6	6 Calanoid copepods plus fragments	55.7	20 Calanoid, 4 Cyclo- poid copepods plus fragments
44.9	6 Calanoid copepods plus fragments	59.3	Empty
45.5	6 Calanoid, 1 Cyclo- poid copepods plus fragments	59.3	1 Calanoid, 5 Cyclo- poid copepods, 2 Larval fish unident- ified. (10.1, 5.0 mm)
46.0	8 Calanoid, 1 Cyclo- poid copepods plus fragments, 1 Amphipod	62.3	90 Calanoid, 20 Cyclo- poid copepods plus fragments, 1 Decopod larva, 1 Larval fish (4.3 mm) unidentified
46.8	18 Calanoid, 10 Cyclo- poid copepods	64.5	3 Euphausiids, many fragments, maybe copepods
46.9	60 Calanoid, 10 Cyclo- poid copepods, 3 Ostracors, 3 Lar- val fish unidenti- fied. (2.3, 5.1, 6.2 mm in length)	81.2	190 Calanoid, 250 Cyclo- poid copepods, 6 Amphipods, 1 Sto- matopod larva, 8 Egalops, 3 Larva! fish unidentified. (5.4, 3.2, 10.0 mm)
47.9	15 Calanoid copepods plus fragments	95.0	45 Calanoid, 90 Cyclo- poid copepods, 3 Decopod larvae, 1 Amphipod, 8 Lar- val fish unidenti- fied (2.4, 5.6, 10.6, 8.3 mm). Rest too damaged
48.2	30 Calanoid, 15 Cyclo- poid copepods plus fragments, 1 Decopod larva		
48.5	80 Calanoid copepods plus many frag- ments		
48.5	Empty		
50.0	7 Calanoid, 1 Cyclo- poid copepods		
51.5	5 Calanoid copepods plus fragments		
53.0	Empty		
54.7	25 Calanoid, 15 Cyclo- poid copepods plus fragments		

Lebour (1919), G. Voss (1953), N. Voss (1954), Legaspi (1956), Clancey (1956) and others have found that copepods constitute a major item in the diet of young fishes. Copepods also proved to be the most commonly encountered food in the guts of postlarval and juvenile specimens of *Caranx crysos*.

Cyclopoid copepods were the only identifiable remains in specimens up to 7.7 mm in length. At 8.5 mm the first calanoid copepods appear and begin to supplement the cyclopoids which are still present. Beyond 10 mm other items appear in the diet, including harpacticoid copepods, ostracods, amphipods, decapod crustacean larvae and fish eggs. The first larval fish appears in the stomach of a blue runner 44.0 mm in length. A specimen 46.9 mm had 3 fish larvae in its gut in addition to copepods and ostracods. The largest specimen examined had the remains of one larval fish in it.

Based on the results of the stomach content examination, it can be stated that *Caranx crysos* at least up to 163.0 mm is a carnivorous plankton feeder. Every specimen except one had planktonic crustaceans in the gut and every specimen except two had identifiable remains of copepods. Throughout the series examined, cyclopoid copepods formed the major part of the diet and a distinct preference for these crustaceans seems evident. Hildebrand and Schroeder (1928) writing on the fishes of Chesapeake Bay, state that adult blue runners are carnivorous, feeding upon other fish.

Temperature and Salinity. The temperatures from the depths at which the specimens were taken ranged from 30.8° to 17.3°C. It is probable that the temperature did not fall below 20°C since the single specimen taken at a temperature of 17.3° came from 438.7 meters, far below the normal range of the species. It seems that the species is normally found above 20°C and is a tropical form. Surface temperatures range from 37.0 to 25.7°C.

Salinity ranged from 33.19 ‰ to 36.24 ‰. The data is far from complete since it is not available from more than 11 stations. This range is typical of open ocean fishes.

There is no significance as to time of day of capture or to the intensity of the isolumens. Specimens were taken throughout the 24 hour period with no predominance at any time of day. The isolumens ranged from 10^2 to 10^6 . For a definition of isolumens see Moore (1950).

DISTRIBUTION

Geographical. All of the records available to the authors from the specimens examined have been compiled on the chart shown in Figure 7. From this it is seen that the species has been reported from Halifax, Nova Scotia, to Recife, Brazil. However, the main concentrations of the species seems to lie within the tropical western Atlantic. Records

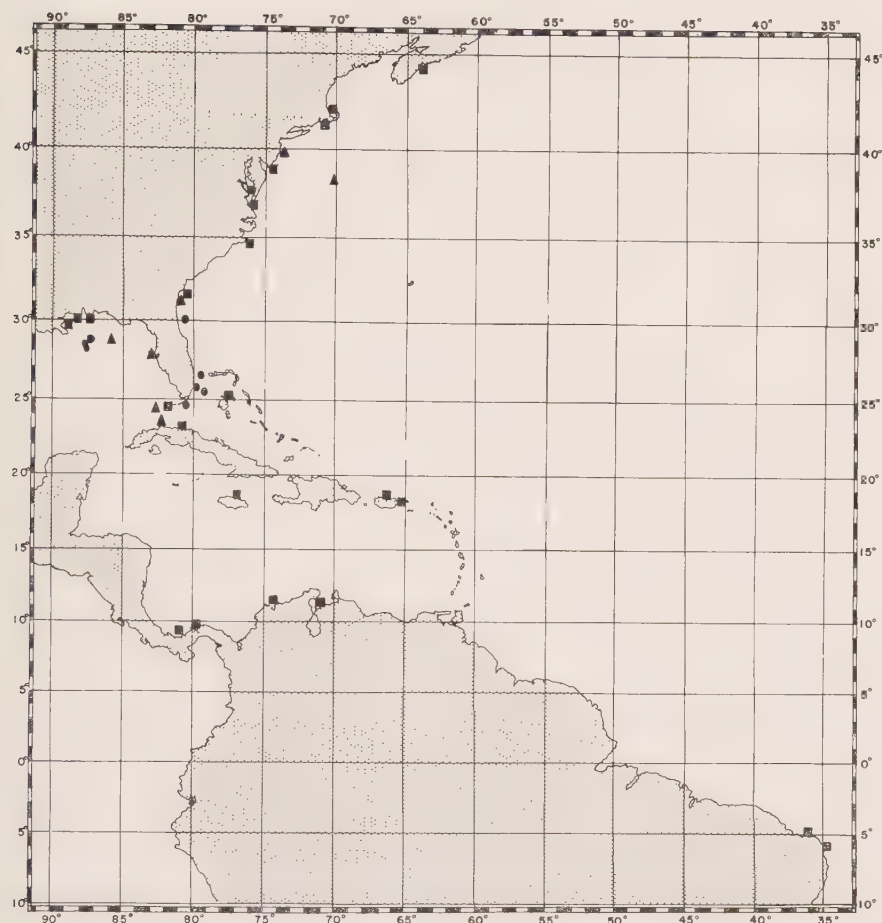


Figure 7. *Caranx crysos* (Mitchill). Geographic distribution of specimens included in this study. Circles, Marine Laboratory specimens; triangles, USNM specimens studied; squares, additional records from collections of USNM.

from outside of the Florida area are mainly from the specimens in the United States National Museum examined by Voss.

During its early life the blue runner is a regular member of the plankton and is carried along with the flow of the Florida Current. As it grows larger it becomes a part of the *Sargassum* complex for a short period. With development into the late juvenile stage the fishes are found distributed both within the Florida Current and along its edge, both scattered and in small to large schools. During the long

summer months the schools extend much farther northward and are found off the Maryland and New Jersey coasts.

Vertical range. Depths from which the specimens were taken are given in Table 1, with the exception of the specimens from the United States National Museum for which these data were unobtainable. With only one exception all of the specimens were taken from the upper 100 meters of water. There is no evidence of any diurnal migration in the larvae of *C. crysos*.

SUMMARY

1. *Caranx crysos*, the blue runner, is a fairly important food and game fish in the West Indies, the Gulf of Mexico and the southeast coast of the United States. It is also extensively used for bait.

2. Postlarvae and juveniles are common in the Florida Straits which probably is a spawning ground for the species. The young have been taken mainly over deep water in the upper 100 meters. No evidence of vertical migration was noted.

3. Adults are primarily inhabitants of shelf and inshore waters and are recorded from Recife, Brazil, to Halifax, Nova Scotia. Their main concentration, however, is within the tropical and warm temperate regions.

4. One hundred and forty-eight postlarval, juvenile and adult specimens were examined and measured. Certain stages of development are figured to show growth changes. Until the stage in which the fin rays are countable, the characters which appear most useful in identifying this species are pigmentation, the presence of an occipital crest, body depth in relation to standard length, the structure of the snout, and the spination of the preopercle.

5. Graphs showing percentages of certain measurements in head length and standard length are presented and discussed.

6. Analysis of stomach contents showed that *C. crysos* is mainly a plankton feeder throughout its larval and early juvenile life and subsists mainly upon cyclopoid and calanoid copepods, the former predominating.

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